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Doubling farmers' income : Scenario, challenges, opportunities and the way forward*

V RANGA RAO

Former Director, ICAR-Indian Institute of Oilseeds Research, Hyderabad-500 030, Telangana; Executive Vice President, ITC (Agribusiness Division-Seeds) and COO (Farm media) of ETV network of TV channels

ABSTRACT

The country's farm sector, the lifeline of economy, has been of late in the throes of a very paradoxical situation namely its shrinking share in country's GDP amidst dependence of close to 60% of country's population on it for their livelihood worsening the agrarian distress and the associated high farmer suicides every year in the face of spectacular performance on the production and productivity front in the form of 'green', 'blue' 'yellow' 'white' revolutions. The average income of more than 60% of farm households in the country with less than one hectare land is hardly a fourth of the current national average per capita income. While no doubt, the farm sector today offers a plethora of avenues for stepping up aggregate production as well as productivity of agri-horti, animal, fish, bird per unit area, input, time and effort, banishing current agrarian distress coupled with doubling farmers' incomes may however, continue to be a vision in spite of all such isolated and fragmented efforts. The paper therefore, calls for an integrated multi-pronged, multi-dimensional initiatives involving production as well as post production chain for translating not only PM's vision into reality at ground level but liberate the much distressed sections of the farm sector, i.e. the millions of small and marginal farmers of the society from their chronic vulnerabilities to weather and market risks, poverty, indebtedness, structural inefficiencies, adverse terms of trade, anti-farmer farm policies, rampant supplies of spurious and substandard inputs and thru it transform their lives and economies.

Keywords: Agrarian crisis, Challenges, Doubling farmers' income, Opportunities, Scenario

The current agrarian crisis on the domestic farm front and the worsening plight of the farmer

Agriculture holds a pre-eminent place in the country's economy in spite of the drastic fall in its share of gross domestic product (GDP), (% share of GDP : 2016-17 = 17.32%; 1950-51 = 49.41%); it forms principal source of livelihood to 58% of its population (and rural India # 68.3%) and provides employment to 2/3 the workforce in the country side (census 2011). The domestic farm scenario has undergone incredible transformation since 1950s, thanks to the technological advances unleashed over the last 40 years and the resilience of Indian farmer to take advantage of emerging opportunities and switch over to newer soil-water-crop-livestock-marine and inland fish culture management systems; the result of all these efforts - quantum jumps in production of food crops (1950-51= 50.82 m.t; 2016-2017 = 275.7 m.t); oilseeds (1950-51= 6.2 m.t ; 2016-17 = 31.3 m.t); cotton (1950-51 = 3.04 m. bales; 2016-17 = 32.6 m. bales), pulses (1950-51 = 8.4 m.t; 2016-17 = 23.0 m.t.); sugarcane (1950-51 = 54.8 m.t; 2016-17 = 303.6 m.t); milk (1950-51 = 17 m.t.; 2016-17 = 163.7 m.t.) eggs (1950-51 = 1.8 billion; 2016-17 = 88.1 billion) and various other farm commodities. Simultaneously, productivity levels of all farm commodities, be it agri-horti or animal, fish, sheep, goat witnessed spectacular growth. Quite paradoxically, the backbone of country's economy, the farmer, who holds today the grandiose encomium 'Annadata', presents a dismal picture amidst his yeoman contribution to the stupendous achievements in the form of green, yellow, blue and white revolutions coupled with food and livelihood security. Over the last two decades, there has been a widening farm- non-farm as well as rural-urban or Bharat-India income inequality. As per report of 70th round of NSSO survey 2002-03 to 2012-13, farmers make on an average, Rs 6426 income per month which is lower than legally laid out minimum wages for unskilled workers in agri-sector and not even 20-25% of either the country's average per capita income or what a lower strata government employee earns today (Dalwai, 2018 and NSSO, 2013). What is worse still, 61 out of 90 million farm house-holds with one or less than one hectare are reported to have a net negative monthly budget (income=Rs 4718; consumption expenditure=Rs 5701; net balance = Rs -983). Added to their extremely low disposable incomes and poverty are the chronic problems of high indebtedness, recurrent crop failures, adverse terms of trade, uncertain and erratic returns to his produce at the marketplace, supply of sub standard and spurious inputs and the associated crop losses. What is more shocking and unnerving is that the incidence of suicides among farmers registered rapid rise in the recent past (average no. of suicides/year over the last 3 years=12000) (National Crime Records Bureau of India). Little surprise, today there is a widespread dis-enchantment among farmers as well as rural youth with farming resulting in growing rural to urban migration, widespread exit syndrome, progressively shrinking gross cropped area and incidence of rampant absentee farming. The yester year's popular adage "farming

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supreme, business good and service worst" has undergone a reversal i.e "service supreme", business "good" and farming "worst".

What ails the country's much talked of 'Annadata'

Contrary to the popular saying by late Pandit Jawaharlal Nehru 'everything can wait but not agriculture', currently, all developmental efforts by the government are focused more towards production and productivity improvement, food security rather than farmer welfare. Today's widespread agrarian distress is a product of cumulative neglect of farmer and his abandonment to the mercy of weather god, exploitative market forces and marketers of spurious farm inputs. As a result, the country's farm sector and its key stakeholder i.e., the farmer is plagued by a plethora of chronic maladies such as weak institutional support systems (credit, service, marketing, input), ineffective risk mitigation mechanisms against weather induced hazards and market driven volatility in prices, flawed land tenure and tenancy, poor infrastructure (irrigation, transport, communication, storage, post harvest processing), far from farmer friendly public policies (marketing, farm trade, exports, farmer subsidies, rural infrastructure, etc), preponderance of extremely small holdings (one hectare or less accounting to 68.5%; 1-2 hectares=17.7%) and the associated dis-economies of scale (Agricultural Census, 2015-16), coupled with widespread rural indebtedness. Needless to overemphasise,all these maladies warrant urgent remedy if we are to improve plight of the country's Annadata.

Mission 2022 of PM and the ambiguity surrounding 'farmer income'

Dr. M.S. Swaminathan, Chairman, National Farmers' Commission in his report recommended for fixation of farm prices at 50 percent above farmers' weighted cost of production; the report is however, silent on which cost whether Comprehensive or C2 costs i.e paid out costs plus interest on fixed capital assets, their depreciation, rent on owned land, or A2 i.e all paid out costs plus imputed family labour (FL). As part of Government's larger strategy for removal of agrarian distress, Prime Minister, Mr. Modi while addressing a Kisan rally in Bareilly on 28 February 2015 gave a clarion call to the nation for doubling the incomes of farmers by the year 2022 on a mission mode. Based on past income growth rates of farmers, Ramesh (2016 and 2017) and the committee on Doubling Farmers' Income (DFI) headed by Dalwai (2018) suggested an annual growth rate of 10.4% for attainment of DFI (real) well on targeted time i.e., year 2022. Ashok Gulati (2018) and Ashok Gulati and Shweta Saini (2016, 2018 and 2018a) were however, highly skeptical of achieving such ambitious growth rates in view of country's poor track record of not only agri growth over the last 4 years (2014-15 to 2017-18=1.9%) but also the lower levels of growth in real farmers' incomes (2012-13 to 2016-17 =2.5%; 2002-03 to 2012-13=3.6% CAGR). Even more pessimistic of Dalwai' (2017 and 2018) and Ramesh (2017) are Thomas and Kaundinya (2018) who projected 25 years for DFI at current 3% agri growth. Given all these and the dependence of net farmers' incomes on a host of factors, both direct and indirect viz., weather, input-output price parity, technology and input levels applied, pricing at market place, transaction costs in marketing, etc. DFI by 2022 in real terms on a sustainable basis may indeed be daunting, if not impossible.

The Finance minister in his 2018 budget speech stated that MSP's in most crops are already fixed at 50 percent over costs and announced his Government's commitment to extend the latter across the board. A perusal of MSPs for 14 kharif crops for 2017-2018 marketing season vis-a-vis CACP's A2 (actual paid out costs including depreciation on implements and farm buildings) plus imputed family labour, (A2 + FL), C2 (i.e., A2 + FL + rental value of own land + interest on value of owned fixed capital assets excluding land) on the contrary, reveals an entirely different picture (CACP, 2017); the Government's declared MSPs are 50% above A2 plus family labour in only 3 out of 14 crops namely bajra, arhar, urad while they are close to production costs in jowar, niger and 17.8 to 43.8% higher in 8 others (CACP, 2017). What is surprising, none of the above crops registered the promised 50 percent higher returns over C2 costs (Table 1). Even those which received higher MSP levels than C2 costs, the extra income fell far short of 50%. Contrary to widespread farmers' expectations and other recommendations of Swaminathan's commission, even the latest MSPs announced by Government of India for kharif marketing season, 2018-19 are nowhere near the promised 50% returns over C2 costs (CACP 2018) vide Table 1. Quite obviously, what the finance minister actually meant when he assured cost plus 50% net returns to farmers over MSPs is cost plus 50% more over A 2 + FL costs rather than C2 costs (Ashok Gulati and Shweta Saini, 2018b). Such a practice is in fact, at total variance with what business enterprises adopt; they take not only paid out costs but a whole lot of indirect costs such as interest on value of owned fixed capital assets, rent on value of owned land (in case of farm sector), depreciation of fixed costs, management input as a pre-determined percentage of total C2 costs (=C3). The adoption of such a discriminatory approach for 'determining what should be the cost plus income' to the farmer in the farm sector which is as much a business enterprise as any other, be it manufacturing or service is not only surprising but grossly unjustified and in contravention of demand of farmer organizations as well as the recommendations of Swaminathan's committee. Farmers are rightly entitled as any other businesses for inclusion of not only all direct but indirect costs in their total costs while fixing MSPs from the point of assured income over his real production costs.

Table 1 MSPs in relation to A2+FL and C2 cost of production of CACP: 2017-18 and 2018-19 marketing seasons

Crops	2017-18 Marketing Season			2018-19 Marketing Season			% change over			
							A2+FL		C2	
	A2+FL	C2	MSP	A2+FL	C2	MSP	2017-18	2018-19	2017-18	2018-19
Paddy*	1117	1484	1550	1166	1560	1750	38.8	50.1	4.4	12.2
Jowar@	1556	2089	1700	1619	2183	2430	9.3	50.1	-18.6	11.3
Bajra	949	1278	1425	990	1324	1950	50.1	97.0	11.5	47.3
Maize	1024	1396	1425	1131	1480	1700	36.5	50.3	2.0	14.9
Ragi	1861	2351	1900	1931	2370	2897	2.1	50.0	-19.2	22.2
Arhar	3318	4612	5450	3432	4981	5675	64.3	65.3	18.2	13.9
Moong	4286	5700	5575	4650	6161	6975	30.1	50.0	-2.2	13.2
Urad	3265	4517	5400	3438	4989	5600	65.4	62.	19.5	12.2
Groundnut	3159	4089	4450	3260	4186	4890	40.9	50.0	8.8	16.8
Soybean	2121	2921	3050	2266	2972	3399	43.8	50.0	4.4	14.4
Sunflower	3481	4526	4100	3592	4501	5388	17.8	50.0	-9.4	19.7
Sesame	4067	5706	5300	4166	6053	6249	30.3	50.0	-7.1	3.2
Niger	3912	5108	4050	3918	5135	5877	3.5	50.0	-20.7	14.5
Cotton+	3276	4376	4020	3433	4514	5150	22.7	50.1	-8.1	14.1

* Common grade varieties; + Medium staple varieties; @ Other than Maldandi varieties

Farmers' income today, Prime Minister's vision, challenges and the way forward:

The accomplishment of mission 2022 of Prime Minister calls for multi-pronged integrated solutions covering a whole spectrum of activities related to not only 'production phase' but also 'post-production' as well as right up to the consumer. The ultimate net income from any farm business enterprise is a function of its unit price of the output x production (= unit productivity x area or size of enterprise) minus total cost of C2 production. One could maximise income from an enterprise by either stepping up productivity levels or by realizing higher unit prices of output or both coupled with /without concurrent reduction in production costs. The farm sector in fact, offers a plethora of options for realising this goal as discussed below:

Raising productivity levels from farming: In spite of the spectacular gains brought about in the general productivity levels of various farm products, be it agri-horti crops, livestock, fish, agro forestry over the last 70 years, there nevertheless, exists even at current levels of technology, wide yield gaps (ranging from 40 to 70%) in different farm commodities. Needless to over emphasize, all such gaps between what is exploitable with the available improved technologies and prevailing yields at field level need to be bridged expeditiously through massive extension and developmental efforts backed up with matching and timely input service support system.

Lowering unit costs of production: Equally wide ranging are the avenues (viz., technological, social, institutional, infrastructural, policy interventions) for cutting down unit production costs in the farm sector and through it step up net realizations. As for instance, the agri sector alone consumes more than 90% of country's ground water resources (and 83% of total water resources); India in fact, uses twice the amount of water to grow crops compared to a country like Israel with extremely scarce water resources. A multitude of proven and cost effective technological interventions are available across geographies in the farm sector to bring down unit costs substantially in conjunction with maximization of resource use efficiency of plant-soil-water and nutrients. These inter alia involve exploitation of state of art region/situation tailored, implementable and cost effective technologies such as micro-irrigation, conservation farming, crop diversification, stepping up cropping intensity through relay/sequence cropping in all assured moisture areas, adoption of recommended agro production-protection practices in tune with appropriate soil and water conservation measures viz., optimum planting time, seeding rates, method and spacing, soil test based balanced nutrient application as per suggested time and placement, integrated pest, disease, weed and water management, adoption of practices such as direct seeding / SRI/ aerobic cultivation in rice, precision and timeliness of critical operations namely inter-culture, irrigation, stage and time of harvest, micro irrigation etc. The successful tapping of all such avenues in synergy with other equally important initiatives discussed elsewhere undoubtedly offers considerable scope to reduce cost of production without affecting output.

Safeguarding farmers against weather risks, natural hazards: Excessive dependence of farming on weather and the impending climate changes pose gravest threat to the livelihood and income security of farmers, bulk of whom are small and marginal. Even after 70 years of planned development, farming in our country continues to be a gamble with the monsoon and its erratic behaviour in space and time (droughts, excessive wet weather, floods, hailstorms, cyclones, etc). Despite a host of national crop insurance schemes since 1980s (NAIS of 1985 and modified NAIS of 1999-2000), risk protection through insurance remains a pipe dream even today; together they account for a negligible share of either total gross cropped area or number of farmers in the country (Banerjee and Bhattacharya, 2011; Raju and Chand, 2008). Notwithstanding its greater acceptability over traditional yield loss assessment or indemnity based crop insurance, the weather based crop insurance scheme is yet to gain foothold because of weak infrastructure backup in terms of automatic weather stations, low earth orbit (LEO) devices, rainfall loggers etc. The situation is no better with the Pradhan Mantri Fasal Bima Yojana (PMFBY) (Targeted coverage by 2018-19 = 50%; actual in a majority of states = 20-25%). This is in contrast to the exceptionally high coverage reported from countries like USA (coverage=90%) and China (coverage=70%) (Ashok Gulati and Hussain, 2018 and Ashok Gulati 2018). Protection of incomes against natural calamities should therefore, form an integral part of doubling income on a sustained basis. This no doubt, calls not only for massive investments in infrastructure, premium subsidies as well as harnessing of latest technologies (satellite imagery, GPS data analytics, drones) but re-tailoring of on-going insurance schemes to suit to ground level priorities and situations together with massive educational efforts for their popularization.

Protection against market volatility in prices and loss of farm incomes: Farmers suffer not only on account of adverse weather aberrations but violent fluctuations in prices as well, more particularly after the advent of globalisation and the emergence of global market place. Unlike developed countries of west, which totally insulate their farmers against volatile price falls or revenue shortfalls through payments in one form or the other (direct, market linked, deficiency), India offers no such luxury to its farmers bulk of whom are small and marginal. Neither the PMFBY nor its predecessor insurance schemes till to-date offer any protection to farmers against market failures. Even the MSPs which GoI offers to 23 crops hardly touch the lives of bulk of the country's 140 million and odd operation farm holdings (Agricultural Census, 2015-16) for want of a guaranteed procurement mechanism in most crops other than rice and wheat (NSSO, 2012-13). Commodity agricultural futures which the national commodity exchanges (NCDEX and MCX) claim to serve as a powerful safety valve to avert farmers' income losses on account of price falls are yet to gain momentum and receive widespread acceptance (% coverage ? 2%).This is not unexpected since the domestic farm sector is dominated by holdings of 2 ha or less (=86.2% of total operational holdings) and their disposable surpluses very low. Imparting economies of scale to small and marginal farmers therefore, holds the key for bringing about any worthwhile and sustainable improvement in their economy.

Minimizing loss of output & incomes on account of poor post harvest processing & storage infrastructure: Apart from weather induced risks and market volatility, not only public & private sectors but farmers suffer considerable quantitative and qualitative erosion of various agri-commodities on account of inefficient harvest, post harvest handling, processing, storage, transport in the on farm-off farm value chain. As per studies of all India coordinated project on post harvest technology (ICAR), PAU, Ludhiana, the extent of total post harvest losses vary from 4.65%-6% in cereals, 6.4%-8.14% in pulses, 3.1%-10% in oilseeds, 6.7% -15% in fruits, 4.6%-12.4% in vegetables, 1.2% - 7.9% in plantation crops to 1% -7.2% in livestock produce (Jha et al., 2015). Even today, the country's post-harvest infrastructure remains abysmally weak. Unlike other countries such as Brazil (70%), Malaysia (83%) only a miniscule of domestic horticultural produce is processed (vegetables 2%; fruits 4%) leading to huge post-harvest losses (Rs. 92651 crores at production levels of 2012-13 and wholesale prices of 2014). Undoubtedly, the food logistics chain in India warrants huge investments for bridging the gaps in scientific post harvest infrastructure.

Creation of conducive and matching farm policy support systems: The pro-consumer agri policies have indeed played havoc with farmers' economy. The latest studies of Organization of Economic Cooperation and Development - Indian Council of Research on International Economic Relations (OECD-ICRIER, 2018) strongly corroborate such a distortion; according to their report, domestic farmers on an average' received, over the last 2 decades, 14% less payments / year than what they otherwise got in the global market place while consumers on the other hand, enjoyed 25% price advantage /year on all commodities. As is obvious from what is highlighted below, the prevailing policy environment is far from farmer supportive in helping farmers achieve either high resource use efficiencies per unit area/input/effort/time and/or quantum jumps in the productivity of agri-horti-livestock-poultry-fish as well as net incomes by harnessing already available technologies in the field:

- Our current fertilizer subsidy policies (nutrient based subsidies, freeing of P and K prices etc) encourage highly imbalanced use of plant nutrients (current N:P:K being 10:4:1; while optimum is 4:2:1) in place of soil test based situation and crop specific nutrient application to the detriment of soil nutritional status (micro and secondary nutrient deficiencies) as well as against farmers' own interests

- Similarly, absence of any rigid water regulatory policies as in countries like Israel with meagre water resources result in inefficient use of precious and scarce water resources (as per National commission for integrated water resources development; water requirement by 2050=1180BCM; present availability = 695BCM) through flooding as well as excessive and liberal applications instead of using more efficient, well established micro irrigation systems (coverage today as per MoAC & FW 2016 = 8.63 m. ha i.e., 6.2% of total sown area of 140 m. ha.) and promotion of water guzzlers like rice, sugarcane at the cost of more efficient water users like oilseeds, millets (eg. sorghum, bajra, maize, etc.), pulses, and horticultural crops. A case in point is Maharashtra which uses 65% of its otherwise scarce irrigation water resources (total irrigated area = 19%; national = 47%) to sugarcane, a very low WUE crop with just 4% of gross cropped area in the state leaving other more efficient crops water starved. The Cauvery basin of Tamil Nadu and Karnataka presents a more or less similar story.

- An yet other area related to critical farm inputs is our growing unabated proliferation of fake and spurious substandard seeds, fertilizers, pesticides, biological and their associated risks i.e. crop losses, inefficient resource use, cost escalation, indebtedness, farmer suicides in the face of continued prevalence of obsolete seed laws of 1968 (and indefinite shelving of more stringent new seed act of 2003), insecticides act (1968) and total absence of any regulations to check rampant supply of substandard and spurious biologicals.

- Equally unfavourable to the domestic producers are a number of other farmer support systems/policies (discussed below) which impact ultimate farmers' costs as well as their margins and operational efficiencies:

- The MSPs which are otherwise considered as a sovereign guarantee to farmers for protection of their investments in the event of price fall below the declared benchmark and ensure reasonable margins over their costs have become no more than a "paper tiger" in as many as 21/23 crops for want of either an assured procurement system (NSSO, 2012-13: per cent farmers selling at MSP <10%) or alternate mechanism for reimbursement of price deficiency over MSP as in case of Madhya Pradesh government's more successful Bhavantar Bhugtan Yojna (BBY). Even in case of BBY of MP traders are reported to manipulate the prices paid to the farmers. Ashok Gulati and Thirtha Chatterjee et al. (2018), Ashok Gulati and Marco Feroni et al. (2018), Ashok Gulati and Shweta Saini (2019) and Swaminathan (2019) are, however, highly critical of not only the current agri price support system/ MSPs but also price deficiency payment schemes, BPY of Govt. of MP or Pan India version "Pradhan Mantri Aay Sanrakshan Abhiyan (PM Aasha) as such interventions not only benefit large farmers with marketable surpluses but also ignore demand side besides distorting market systems i.e., depress prices and lead to unwanted surpluses. Instead, they advocate adoption of least market distortionary, crop neutral, highly transparent intervention policy in the form of direct investment/income support on the lines of Government of Telangana's "Rythu Bandhu" scheme (RBS) of payment of Rs. 4000/acre per season to every land owning farmers (both in kharif and rabi seasons) or more preferably the modified adaptation of RBS of Odisha namely, Kalia i.e., Krushak Assistance for Livelihood and income assistance which not only excludes large farmers from its ambit, but, includes tenants, share-croppers as well as landless rural households. As per cost estimates of Ashok Gulati and Saini (2019) extension of the above income transfers in the extended format i.e., inclusion of tenants is projected to cost Rs. 2 trillion when compared to Rs 4-5 trillion of pan India farm loan waivers.

- The land market which in fact, is the key driver for stepping up "productivity", "efficiency" and " "investment" of millions of small and marginal farms in the country side is seriously constrained on account of inaccurate/incomplete land records (titles, ownership/tenancy, size, boundaries etc.) and the associated high transaction costs including civil litigations. Equally to blame for today's 'unsustainable' farm holdings 'growing exit' syndrome or withdrawal from cultivation is the reluctance of land owners to lease out their land assets for fear of threat from tenants under the draconian tenancy act which is skewed in favour of the latter and the absence of proper land leasing policies so essential for overcoming dis-economies of scale and improve efficiencies of small and marginal farm holdings, besides promoting their diversification. As per reports of Shreya Deb (2018), un-official leasing figures (25% or more) far exceed those of official tenancy estimates of 13% (NSSO, 2013). What is worse, the prevailing norms do not allow lessee farmers access credit from formal banking institutions without compromising on the land owners' rights leaving the farmer no option but to rely on private money lenders. All this only underlines the urgent need for streamlining our system of land administration using state of the art technologies/tools (geospatial drones, digital) together with transparent and liberalized land lease policies benefitting all concerned i.e., land owners as well as tenants and share-croppers through adoption of model land leasing act of MOAC and FW across the country.

- The introduction of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) has adversely impacted not only labour availability in rural heartland but pushed up labour costs in times of crucial agricultural operations. This warrants re-appraisal of MGNREGA vis-a-vis the concerns of farm sector to make it a win-win proposition i.e., deployment of agricultural labour in times of critical agricultural operations for overcoming labour shortages.
- Equally to blame are faulty and knee jerk import-export policies viz., liberal imports through very low import tariffs in domestically high sensitive commodities like edible oils despite availability of very high bound rates (~300%), or restrictive ad hoc export policies (stock controls for private players, controls on future trading, adhoc export bans, minimum export prices) in times of either bumper domestic production and/or high domestic prices to the utter disadvantage of domestic producers (Ashok Gulati and Terway, 2017)
- Competitive loan waivers by states have of-late become a norm rather than an exception in their race to capture traditional vote banks and capitalize on farmers' distress. Interestingly, according to the situation assessment survey of agricultural households of NSSO (2013); less than 40% of marginal farmers availed loans from institutional sources as against 80% of large farmers. Judging from the above skewed picture as well as the findings of NABARD (2017) on per cent of farmer borrowers depending on institutional sources (30%) such a move would benefit only limited number of farmers that too mostly large farmers who constitute a miniscule per cent of total operational holdings (0.57%; small and marginal 86.2%) (Agricultural Census, 2015-16). Such temporary palliatives not only fail to address agrarian distress but also destroy the very credit culture as well as repayment discipline and may lead to recurrent demands. What the farmers need is not such ad hoc remedies but creation of income generating avenues in the off-farm domain akin to what services did in the urban sector through transformation of rural area into manufacturing hubs of post-harvest value chain from farm to fork on lines of Amul model in conjunction with much awaited structural reforms in agri-sector.
- Our key investment policies in the country's most crucial sector i.e., farm sector continue to be overwhelmingly biased towards food and input subsidies neglecting the crucial agri infrastructure; in fact, public investments in agriculture as a percentage of agri-GDP has declined from 3.9% in 1980-81 to 2.2% in 2014-15 while input subsidies increased from 2.8% to 8.0% over the same time span (Ashok Gulati Marco Feroni et al , 2018); this is too glaring from a cursory look at expenditure bill of 2018-19 for agriculture and food (total bill = Rs. 3.66 lakh crores; input and food subsidies = 88%; agri-investment =12%). No surprise, if our per capita water storage capacities are very low (=213CM) compared to other countries (China = 1111 CM; Australia = 4733 CM; USA = 1964 CM) even after building large number of large and small dams (Niti Aayog, 2018). Despite creation of long-term irrigation fund (LTIF) with NABARD (=Rs. 40,000/- crores) there is as yet no worthwhile progress. Unless such imbalances in our agri investments are rectified and farm infrastructure gets a major boost, raising productivity and economies of millions of small and marginal farms would continue to elude us.
- To-date, there is no system of either reliable advance forecasts on prices of agri-commodities and/or dynamic intelligence on crop acreage and production via-a-vis demand as the season progresses. The absence of such crucial advance intelligence despite tremendous technological breakthroughs in satellite technology and digital revolution naturally deprives domestic farmers any opportunities for adjustment of their cropping patterns in tune with the emerging market demands.
- The model APMC (Development and Regulation) act which was introduced way back in 2003 by GoI as part of its larger national objective to establish more efficient, transparent and integrated marketing system is yet to be translated into field reality in most states. The existing agricultural marketing under APMC act in states and their poor infrastructure, monopsonistic and uncompetitive policies have only perpetuated fragmentation and inefficiencies with huge number of intermediaries. The involvement of too many intermediaries in the value chain under the current agri-marketing system continues to be the major constraint responsible for the extremely low share of farmers in the ultimate consumers' rupee. Contract farming which is permitted under the modified state APMC acts of 2003 though offers considerable avenues to farmers to minimize their risks on account of market volatility and leverage on improved access to technology as well as inputs has not yet become very popular because of one or the other inherent limitations. The recently launched "Agriculture produce and livestock contract farming and services (promotion and facilitation) act, 2018 which is outside the ambit of APMC acts of

states is expected to receive patronage from all stakeholders i.e., farmers, agro industry, retail chains as it removes all current hurdles. Though e-NAM is expected to free farmers from the monopoly of APMCs and provide them access to unified national marketing platform with attendant advantages (dis-intermediation, transparency, wastage control), it's penetration and reach to date is too low (585/6615 regulated markets under APMC) to create any visible impact in the immediate future on account of numerous constraints (continued non-amendment of APMC Acts by a number of states, poor infrastructure, etc.).

- Although farmer producer organisations (FPOs) viz., cooperatives, farmer produced company (FPCs), self-help groups, farmer interest groups, not only offer viable and sustainable institutional solution for tackling the vexed problem of dis-economy of scale of millions of small farms and harness the multitude of benefits, the later offers (viz. enhanced bargaining power through forward and backward linkages and their associated advantages i.e., mobilisation of quality input supplies, aggregation of output, their marketing including leveraging futures as an effective tool, custom services at lower cost and the resultant reduced transaction costs in marketing, direct marketing, etc.), they remain till to-date grossly under-exploited unlike in dairy and sugarcane (total number of FPCs today <3000; requirement of rural India = 1.0 lakh) on account of inherently weak support system (collateral free institutional finances at attractive rates of interest, post-harvest infrastructure, integration with value chain, access to capital and technology, etc.). The success stories of large number of FPOs in the country (Kolhapur Sugar Co-operatives, Sahyadri Farms, Nasik - a network of FPCs, Vasundhara Agri-Horti Producer Co. Ltd., (VAPCOL), Pune; Mahagrapes and Hivre Bazar of Maharashtra; Gujarat Agri-Business Consortium Producer Co., (GUJPRO), Mulakanur Cooperative of Telangana), only underlines the urgent need to dissuade farmers from current political/casteist grouping and organise them into need based FPOs of one form or the other and through it help the latter help themselves improve their collective bargaining power as well as voice and solve their problems; otherwise freeing farmers from current agrarian crisis and the associated maladies (viz., widespread poverty, rural indebtedness, livelihood insecurity, and Damocles' sword of suicides hanging over their heads) would be an eternal mirage.

What is therefore urgently needed, if PM's vision of DFI on a sustained basis is to be made a reality in tune with improved livelihoods of millions of farm households including the workforce the latter supports, is the speedy rectification of all these and various other loopholes in our farm policies together with creation of mutually reinforcing and synergistic policy environment and supportive infrastructure in the form of post harvest processing facilities including storage, transport, market linkages with the value chains.

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Genetic variability, correlation and path analysis in fastigiata and hypogaea sub-species of groundnut (*Arachis hypogaea* L.)

SIMA SINHA, M H RAHMAN, ANIL KUMAR VERMA AND CHANDAN KISHORE

Bihar Agricultural University, Sabour-813 210, Bihar

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ABSTRACT

The investigations on the genotypic and phenotypic variability, correlations and path coefficient analysis were conducted for nine characters in twenty genotypes each for two sub species of groundnut namely fastigiata (Spanish/Valencia) and hypogaea (Virginia). Analysis of variance revealed significant differences among the genotypes for all characters except per cent of sound mature kernel in fastigiata (Spanish) group. The magnitude of phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) was larger for number of primary branches and 100 kernel weights in hypogaea than fastigiata sub-species. Number of pods per plant in hypogaea showed greater heritability than fastigiata. Genetic advance as per cent of mean for number of pods per plant, 100 kernel weight and pod yield per plant displayed better estimates in hypogaea whereas length of primary branches, height of main axis and 100 kernel weight were higher in fastigiata sub-species. Number of pods per plant was highly significant and positive with pod yield per plant in both sub-species while number of primary branches and percentage of oil was positive and highly significant only in case of hypogaea sub-species. Path coefficient analysis exhibited that the length of primary branches, number of pods per plant, 100-kernel weight and percentage of oil were important for yield improvement in both sub-species of groundnut.

Keywords: GCV, Genetic Advance, Groundnut, Heritability, PCV, Variability

Groundnut (Arachis hypogaea L.) is a major source of protein and is also majorly used for production of edible oil. Among the edible oilseed crops, it is important to poor farmer as a food and cash crop. The two botanical sections of Arachis hypogaea differ in their distribution of vegetative and reproductive branches in the axis of leaves on the main axis and the branches. In Virginia (hypogaea) group, the first two nodes of n+1 branch are normally vegetative and the next two nodes bear inflorescence and next two are again vegetative branches and so on. This system was termed as alternate branching pattern by Bunting (1955). In the Spanish-Valencia (fastigiata), reproductive branches are borne at the second and several subsequent nodes of primary branches. The first node on such a branch may bear secondary branch (n+2) but often it too bears inflorescence. This allows the first flowers to be initiated very soon after the development of n+1 branch and this system is termed as sequential branching. The variability present in this crop needs to be exploited to improve the yield potential of the existing cultivars which has already reached the ceiling. The present study was taken up to understand the variability present in a set of genotypes that included both the botanical subtypes of groundnut.

MATERIALS AND METHODS

The present study was carried out at Ranchi Agricultural College, Kanke, Ranchi. It is situated in the plateau region of Bihar at a latitude and longitude of 23o-1'N and 85o19'E respectively while having an altitude of 625 meters above sea level. The experimental material comprised of 20 bunch genotypes each from sub-species fastigiata and hypogaea (Virginia). The experiment was conducted in randomized block design with three replications adopting a spacing of 15 cm from seed to seed and 30 cm between rows. Five plants were randomly selected from each plot to record the data for nine quantitative traits viz. height of main axis (cm), no. of primary branches, length of primary branches (cm.), no. of pods/ plant, percentage of shelling, percent of sound mature kernel, percentage of oil, 100-kernel weight (g) and pod yield/ plant (g). PCV and GCV were calculated by the method given by Burton (1952), heritability in broad sense and genetic advance was estimated by using the method of Lush (1940) and Johansen et al (1955). Correlation coefficient was calculated by the method given by Aljibouri et.al (1958) and Panse and Sukhatme (1967). Path coefficient analysis was done by the method advocated by Dewey and Lu (1959). List of genotypes included in the study are given in the Table 1.

RESULTS AND DISCUSSION

The range of variation showed a similar trend in both the sub-species for most of the characters. The characters, namely number of pods/plant, shelling percentage, 100-kernel weight and pod yield/plant in hypogaea sub species exhibited a wider range of variation than fastigiata sub species (Table 2).

Maximum range was obtained in fastigiata (Spanish/ Valencia group) for length of primary branches (33.16 to

Corresponding author's E-mail: simasinha11@gmail.com;
[1]Department of Plant Breeding and Genetics, BAU, Kanke

69.82 cm) and for 100- kernel weight it was highest in hypogaea (Virginia group) (37.07 to 105.19 g). Analysis of variance for nine quantitative characters in both the sub-species (fastigiata and hypogaea) exhibited significant differences among the genotypes for almost all characters except percentage of sound mature kernel in Spanish (fastigiata) group. It indicates that variability was present in considerable amount in the experimental material.

Phenotypic coefficients of variation (PCV), which measures the total relative variation, was huge for pod yield/plant (30.429), number of pods/plant (23.447), height of main axis (22.232) and length of primary branches (21.782) for fastigiata group. While in the case of hypogaea group, number of pods/plant (38.181), 100- kernel weight (36.069) and pod yield/plant (36.030 g) had higher phenotypic coefficients of variation. These results were in accordance with the findings of Deshmukh et al. (1986), Shoba et al. (2012) and Thakur et al. (2011). Fastigiata had greater values of genotypic coefficients of variation for pod yield/plant (28.876), height of main axis (21.296) and length of primary branches (20.851) whereas, higher values for 100-kernel weight (35.835), pod yield/plant (34.590) and number of pods/plant (34.446) were observed for hypogaea group. Similar results were reported by Nath et al. (2002), Deshmukh et al. (1986) and Kadam et al. (2009). The estimates of phenotypic variance were found to be more than genotypic variance for all the characters in both the sub-species. This indicates that the environmental variance contributes to the total variance. Largest values for PCV and GCV among fastigiata and hypogaea sub-species were observed for length of primary branches and 100-kernel weight respectively followed by height of main axis. Highest PCV and GCV were recorded in fastigiata for pod yield/plant, whereas, in hypogaea group 100- kernel weight and number of pods/plant. The results were supported by Sangha (1973) and Surbhi et al. (2016).

Both the sub species exhibited high heritability (90.05 to 98.71%) for height of main axis, length of primary branches, 100-kernel weight and pod yield/plant. However, higher heritability was observed in hypogaea sub spp. with respect to number of primary branches, number of pods/plant and percentage of shelling. Similar results for heritability had also been reported by Lakshmaiah (1983), Kulkarni and Albuquerque (1967), Dixit et al. (1970) (for number of primary branches), Sangha and Sandhu (1970), Singh et al. (1975), Thakur et al. (2011) and Deshmukh et al. (1986) (for 100-kernel weight), Balaiah and Reddy (1977) for number of pods/plant. The larger heritability in a broad sense will be reliable if accompanied by higher genetic advances. Greatest heritability was observed for the height of main axis followed by length of primary branches in fastigiata genotypes whereas in case of hypogaea type 100-kernel weight had the highest heritability followed by length of primary branches. Both the sub-species exhibited huge genetic advance in per cent of mean coupled with sizeable heritability for the height of main axis, length of primary branches, 100- kernel weight and pod yield/plant. Similar results on hypogaea sub-spp. were obtained by Sangha (1973), for number of mature pods, 100- kernel weight and pod yield. Genetic advance as per cent of mean obtained by Prasanthi et al. (1990), Abhay et al. (2002), Thakur et al. (2011) and Sah et al. (2000) for height of main axis, shelling per cent, 100-kernel weight and pod yield/plant also corresponds with the present findings. Large genetic advance expressed in per cent of mean was obtained for pod yield/plant followed by height of main axis in case of fastigiata groundnut, whereas maximum genetic advance in per cent of mean was obtained for number of pods per plant followed by 100-kernel weight in hypogaea subspecies.

Findings were in accordance with Surbhi et al. (2016), John et al. (2013) and Thakur et al. (2011). Positive significant correlation between height of main axis and length of primary branches genotypically (0.9872**) as well as phenotypically (0.9436**) was observed from the results of fastigiata sub-spp. Number of pods/plant also showed positive and significant correlation with pod yield/plant both genotypically (0.7593**) as well as phenotypically (0.4648*). However, negative significant correlation was obtained between length of primary branches and shelling percentage. Percentage of oil was also found to be positive but non-significant correlation with pod yield/plant.

Data of hypogaea groundnut revealed that large positive and significant correlation existed between length of primary branches and number of primary branches in both genotypically (0.9482**) as well as phenotypic ally (0.9834**). Number of primary branches, number of pods/plant and percentage of oil displayed highly significant positive correlation with pod yield/plant. 100- Kernel weight was also positive and significantly correlated with height of main axis. Thus, positive and significant correlation of height of main axis with length of primary branches and number of pods/plant with pod yield/plant were obtained in both the sub-sp. of groundnut. A positive significant genotypic and phenotypic association of number of pods/plant with number of primary branches was also reported by Nag Bhushanam et al. (1982). A positive and significant correlation between the number of pods/plant and oil percentage with pod yield corresponded with the findings of Deshmukh et al. (1986), Manoharan et al. (1989), Surbhi et al. (2016), Mathews et al. (2000), Nagda et al. (2004), Kumar et al. (1998) and Kadam et al. (2009).

The path analysis was utilized in finding out direct and indirect causes of association and allowed detailed examination of specific forces acting to produce a given correlation and measured the relative importance of each causal factor. Of all the characters included in the path analysis for fastigiata sub species, it was revealed that four characters had direct effect on pod yield at phenotypic level. The direct effect of 100-kernel weight phenotypically on pod yield among fastigiata was found to be big (0.4837) with high heritability and genetic advance in per cent of mean. This trait will be considered useful in making selections among fastigiata sub species of groundnut. In references Badwal & Gupta 1968 is given and Prasanthi et al. (1990) also reported significant effect of kernel weight on pod yield in hypogaea. The length of primary branches demonstrated high heritability with large genetic advance in per cent of mean in both the sub-species of groundnut. Percentage of oil appeared to be comparatively low direct effect (0.1936) on pod yield. However, its indirect effect on pod yield via length of primary branches was negative. Khangura and Sandhu (1972), Mathew et al. (2000), Sah et al. (2000) and Kadam et al. (2009).

Table 1 List of genotypes in fastigiata and hypogaea sub-species of groundnut

S.No	Fastigiata (20)			S.No	Hypogaea (20)		
1	AK-12-24	11	DH 39	1	JSSP -5	11	ICGV-86300
2	JL-24	12	k-134	2	JSSP-6	12	NFP-140
3	GG-2	13	ICGV-87287	3	JSSP-7	13	S-5
4	Gangapuri	14	RG-97	4	NRGS- 9	14	BAU-6
5	Kisan	15	KGN-3	5	DRG-13	15	BAU-12
6	OG-85-1	16	J-27	6	DRG-17	16	BAU-13
7	TG-22	17	J-29	7	DRG-18	17	BAU-16
8	TG-24	18	DRG-12	8	CSMG-909	18	BG-1
9	TG-25	19	R-8808	9	Kadiri-3	19	BG-2
10	TG-26	20	R- 9021	10	ICGV-65	20	BG-3

Table 2 Range, Mean, Standard error from Mean and CD of nine characters of groundnut

Characters	Fastigiata		Hypogaea		Fastigiata		Hypogaea	
	Range	Mean	Range	Mean	S.E from mean	CD at 5%	S.E from mean	CD at 5%
Height of main axis (cm)	31.80 - 63.57	43.22	23 -59.80	40.44	± 1.553	4.51	±1.441	4.23
No. of primary branches	3.23 – 4.20	3.89	3.27 – 6.80	4.34	±0.121	0.35	±0.235	0.69
Length of primary Branches (cm)	33.16 – 69.82	45.76	29.79 – 67.15	46.75	±1.619	4.70	±1.379	4.05
No. of pods/ plant	9.47 – 16.47	13.19	7.27 – 29.07	16.28	±1.489	4.32	±1.509	4.43
Percentage of shelling	62.36 – 74.75	70.10	43.73 – 73.43	66.63	±1.209	3.51	±1.101	3.23
Sound mature kernel %	78.19 – 96.69	92.20	84.25 – 97.86	91.61	±3.255	6.57	±2.070	6.08
Percentage of oil	45.77 – 51.09	49.06	47.95 – 53.30	50.39	±0.706	2.05	±0.775	2.76
100-Kernel weight (g)	28.22 – 58.53	37.66	37.07 – 105.19	52.33	±1.207	3.5	±1.211	3.56
Pod yield/plant	5.99 – 19.23	11.02	8.21 – 30.33	15.68	±0.595	1.73	±0.890	2.61

Table 3 Estimates of phenotypic (?2 ph), genotypic (?2g) and error (? 2 e) variance and phenotypic and genotypic coefficient of variability (PCV & GCV) for nine characters of groundnut in fastigiata and hypogaea sub-species

Characters	σ2 ph		σ2g		σ 2 e		PCV		GCV	
	Fastigiata	Hypogaea	Fastigiata	Hypogaea	Fastigiata	Hypogaea	Fastigiata	Hypogaea	Fastigiata	Hypogaea
Ht of main axis (cm)	92.338	129.456	84.725	122.907	7.613	6.552	22.232	28.136	21.296	17.411
No. of primary branch	0.0951	0.973	0.049	0.798	0.046	0.175	7.904	22.611	5.674	20.482
Lt of primary Branch	98.907	122.233	90.627	116.230	8.280	6.003	21.782	23.647	20.851	23.059
No. of pods per plant	9.560	38.653	2.560	31.461	7.000	7.192	23.447	38.181	12.133	34.446
Percentage of shelling	11.888	52.447	7.271	48.619	4.617	3.827	4.918	10.868	3.846	10.646
Sound mature kernel %	41.806	22.027	8.357	8.499	33.482	13.528	7.048	5.132	3.151	3.188
Percentage of oil	2.859	3.678	1.286	1.782	1.573	1.896	3.448	3.805	2.313	2.648
100-Kernel weight (g)	52.005	357.918	47.408	353.286	4.597	4.632	19.147	36.069	18.281	35.835
Pod yield per	11.233	31.908	10.115	29.409	1.117	2.499	30.429	36.030	28.876	34.590

Table 4 Estimates of heritability, genetic advance and genetic advance expressed as percentage of mean in fastigiata and hypogaea sub-species

Characters	Heritability		Genetic Advance		Genetic advance in % of mean	
	Fastigiata	Hypogaea	Fastigiata	Hypogaea	Fastigiata	Hypogaea
Height of main axis (cm)	91.76	94.94	18.163	22.252	42.025	55.025
No. of primary branches	51.54	82.05	0.327	1.667	8.406	38.410
Length of primary Branches (cm)	91.63	95.09	18.772	21.657	41.023	46.325
No. of pods per plant	26.78	81.39	1.706	10.424	12.934	84.945
Percentage of shelling	61.16	92.70	4.334	13.829	6.197	20.755
Sound mature kernel %	19.19	38.58	2.663	3.730	2.888	4.072
Percentage of oil	44.99	48.44	1.567	1.914	3.194	3.798
100-Kernel weight (g)	91.16	98.71	13.542	38.468	35.595	73.524
Pod yield per	90.05	92.17	6.217	10.725	56.416	68.390

Table 5(a) Genotypic (G) and phenotypic (P) correlation between different pairs of character of fastigiata groundnut

Characters		No. of primary branches	Length of primary branches	No. of pods/ plant	Shelling %	Sound mature kernel %	Oil %	100-Kernel weight	Pod yield/ plant
Height of main axis	P	0.2049	0.9436**	-0.0238	-0.3987	-0.0355	-0.3033	-0.3344	0.0057
	G	0.2231	0.9872**	-0.0800	-0.5361	0.0728	-0.4697*	-0.3552	-0.0087
No. of primary branches	P		0.1713	0.3313	-0.2922	-0.0317	0.0035	0.1812	0.2184
	G		0.1536	0.5622**	-0.4008	-0.2710	-0.2465	0.2246	0.3470
Length of primary Branches	P			-0.0034	-0.4663**	-0.0029	-0.2871	-0.3252	0.0849
	G			-0.1375	-0.5769**	0.0419	-0.4590*	-0.3576	0.0698
No. of pods per plant	P				0.0077	-0.0588	-0.1088	-0.0139	0.4648*
	G				0.0435	-0.8317**	-0.1144	-0.0608	0.7593**
Percentage of shelling	P					-0.0086	-0.0298	-0.0083	-0.3616
	G					0.1060	-0.0691	-0.0447	-0.4768
Sound mature kernel %	P						-0.1316	0.1531	-0.1651
	G						-0.3690	0.3459	-0.3210
Percentage of oil	P							0.0158	0.1347
	G							0.0377	0.1842
100 Kernel weight	P								0.3704
	G								0.4228

* = Significant at 5 level (r = .444); ** = Significant at 1 level (r = .561)

Table 5(b) Genotypic (G) and phenotypic (P) correlation between different pairs of character of hypogaea groundnut

Characters		No. of primary branches	Length of primary branches	No. of pods/ plant	Shelling %	Sound mature kernel %	Oil %	100-Kernel weight	Pod yield/ plant
Height of main axis	P	-0.1019	0.9482**	-0.0912	0.0548	-0.1620	0.2499	0.4626*	0.3250
	G	-0.1178	0.9834**	-0.1274	0.0414	-0.2318	0.3769	0.4779*	0.3459
No. of primary branches	P		-0.0347	0.7095**	-0.7424**	-0.1294	0.3594	-0.2437	0.6955**
	G		-0.0434	0.7810**	-0.8309**	-0.0626	0.6310**	-0.2653	0.7751**
Length of primary Branches	P			-0.0261	0.0153	-0.1064	0.2967	0.3134	0.3828
	G			-0.0437	-0.0106	-0.1895	0.4128	0.3266	0.4007
No. of pods per plant	P				-0.5076	-0.1785	0.2416	-0.4501*	0.6879**
	G				-0.5840	-0.1213	0.4858	-0.5006*	0.7537**
Percentage of shelling	P					0.0471	-0.3080	0.0081	-0.7532**
	G					0.1301	-0.5161	0.0094	-0.8068**
Sound mature kernel %	P						0.1221	-0.1766	-0.1505
	G						0.0032	-0.3005	-0.3171
Percentage of oil	P							-0.0273	0.4871*
	G							-0.0357	0.6718**
100 Kernel weight	P								-0.0002
	G								0.0055

* = Significant at 5 level (r = .444); ** = Significant at 1 level (r = .561)

Table 6(a) Partitioning of correlation into direct (diagonal) and indirect effects by path analysis in fastigiata groundnut for pod yield per plant

Characters		X1	X2	X3	X4	X5	X6	X7	X8	Correlation with pod yield/plant
Height of main axis (X1)	P	-0.2811	-0.0576	-0.2652	0.0067	0.1121	0.0100	0.0852	0.0940	0.0057
	G	4.8175	1.0750	4.7558	-0.3856	-2.5828	0.3508	-2.2627	-1.7112	-0.0087
No. of primary branches (X2)	P	-0.0331	-0.1615	-0.0277	-0.0535	0.0472	0.0051	-0.0006	-0.0293	0.2184
	G	-0.2612	-1.1706	-0.1798	-0.6582	0.4692	0.3173	0.2886	-0.2630	0.3470
Length of prim. Branches (X3)	P	0.4232	0.768	0.4484	-0.0015	-0.2091	-0.0013	-0.1288	-0.1459	0.0940
	G	-5.3916	-0.8391	-5.4615	0.7512	3.1506	-0.2289	2.5066	1.9532	0.0698
No. of pods per plant (X4)	P	-0.0126	0.1761	-0.0018	0.5316	0.0041	-0.0313	-0.0578	-0.0074	0.4648
	G	0.0441	-0.3099	0.0758	-0.5513	-0.0240	0.4585	0.0631	0.0335	0.7593
Shelling % (X5)	P	0.1227	0.0899	0.1435	-0.0024	-0.3078	0.0026	0.0092	0.0026	-0.3616
	G	0.7114	0.5319	0.7655	-0.0577	-1.3269	-0.1407	0.0916	0.0594	-0.4768
Sound mature kernel % (X6)	P	0.0071	0.0063	0.0006	0.0117	0.0017	-0.1988	0.0262	-0.0304	-0.1651

Table 6 (b) Partitioning of correlation into direct (diagonal) and indirect effects by path analysis in hypogaea groundnut for pod yield per plant

Characters		X1	X2	X3	X4	X5	X6	X7	X8	Correlation with pod yield/plant
Height of main axis (X1)	P	-0.0456	0.0046	-0.0432	0.0042	-0.0025	0.0074	-0.0114	-0.0211	0.325
	G	-10.9838	1.3040	-10.8017	1.3989	-0.4545	2.5463	-4.1395	-5.2492	0.3459
No. of primary branches (X2)	P	0.0015	-0.0146	0.0005	-0.0103	0.0108	0.0019	0.0052	0.0036	0.6955
	G	0.1654	-1.3929	0.0604	-1.0879	1.1573	0.0872	-0.8777	0.3696	0.7751
Length of prim. Branches (X3)	P	0.3463	-0.0127	0.3652	-0.0095	0.0056	-0.0389	0.1084	0.1144	0.3828
	G	10.0197	-0.4418	10.1886	-0.4450	0.1082	-1.9305	4.2061	3.3277	0.4007
No. of pods per plant (X4)	P	-0.0440	0.3425	-0.0126	0.4828	-0.2450	-0.0862	0.1166	-0.2173	0.6879
	G	-0.1832	1.1233	-0.0628	1.4383	-0.8399	-0.1745	0.6987	-0.7201	0.7537
Shelling % (X5)	P	-0.0264	0.3573	-0.0074	0.2443	-0.4813	-0.0227	0.1482	-0.0039	-0.7532
	G	-0.0191	0.3836	-0.0049	0.2696	0.4617	-0.0601	0.2383	-0.0043	-0.8068
Sound mature kernel % (X6)	P	0.0010	0.0008	0.0007	0.0011	-0.0003	-0.0061	-0.0007	0.0011	-0.1505
	G	0.0242	0.0065	0.0198	0.0127	0.0136	-0.1045	-0.0003	0.0314	-0.3171
Oil % (X7)	P	0.0337	0.0484	-0.0400	0.0325	-0.0415	0.0164	0.1347	-0.0037	0.4871
	G	0.2365	0.3953	0.2590	0.3048	-0.3238	0.0020	0.6274	-0.0224	0.6718
100 Kernel weight (X8)	P	0.0586	-0.0309	0.0397	-0.0571	0.0010	-0.0224	-0.0035	0.1268	-0.0002
	G	1.0862	-0.6030	0.7423	-1.1378	0.0213	-0.6830	-0.0812	2.2729	0.0055

Height of main axis though showed negative direct effect, its indirect effect via length of primary branches and shelling percentage was large which nullifies the negative direct effect. Height of main axis also displayed high heritability coupled with genetic advance in per cent of mean.

Among the hypogaea sub species, the number of pods/plant had maximum direct positive effect on pod yield/plant phenotypically as well as genotypically having significant heritability with high genetic advance in per cent of mean. The direct effect of length of primary branches on pod yield was found to be 0.3652, which also had sizeable heritability coupled with high genetic advance in per cent of mean. The percentage of oil also had direct effect on pod yield in hypogaea sub-species and indirect effect via length of primary branches, number of pods per plant and percentage of shelling. The number of primary branches was found to have negative direct effect (0.0146) but it was nullified by high indirect effect via percentage of shelling (0.3573) and number of pods per plant (0.3425). This corresponds with the findings of Khangura and Sandhu (1972), Deshmukh et al. (1986), Surbhi et al. (2016), and Nagda et al. (2004).

On the basis of genotypic and phenotypic variability, correlation and path analysis, we found that the selections could be based on 100-kernel weight in fastigiata and hypogaea sub-species. Selections are important for future improvement of groundnut program based on number of primary branches and percentage of oil. The selection for the character number of pods/plant and length of primary branches will be more reliable for both fastigiata and hypogaea sub-species of groundnut.

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General combining ability of parents and specific combining ability of crosses for yield and oil related traits in sunflower (*Helianthus annuus* L.)

K VARALAKSHMI* AND S NEELIMA

Agricultural College, Mahanandi-518502, Acharya N G Ranga Agricultural University, Andhra Pradesh

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ABSTRACT

Twenty four hybrids along with ten parents and four standard checks were evaluated in a Randomized block design with two replications at Regional Agricultural Research Station, Nandyal during rabi, 2018-19. The analysis exhibited significant differences among lines for ten traits and testers for nine traits. The lines x tester interactions were significant for eleven traits. The mean squares with respect to crosses were significant for all the characters except stem girth. The GCA and SCA variances revealed existence of non-additive gene action for most of the traits. The parental line CMS 30 A was a good general combiner as it possessed significantly high GCA effects for most of the economic traits like leaf area index, plant height, head diameter, number of leaves per plant, days to maturity, 100 seed weight, autogamy per cent, seed yield, hull content, oil content and oil yield, while NDLA-4 was a good general combiner for specific leaf area, number of leaves per plant, number of seeds per head and volume weight. The tester NGM-16 was a good general combiner for seed yield and yield component traits. The crosses NDLA-3 x NO-30, CMS-30 A x R-106 and NDLA-4 x NGM-16 were promising hybrid combinations for seed yield with regard to specific combining ability (SCA) effects and these hybrids could be tested in multi location trials further if they have exploitable level of commercial heterosis.

Keywords: Combining ability, GCA, Line x Tester, SCA, Sunflower

Sunflower is an important oilseed crop which can be grown in varied climatic and soil conditions in any season of the year. A high degree of cross pollination coupled with availability of efficient cytoplasmic male sterility and fertility restoration systems offers considerable scope for commercial exploitation of heterotic hybrids. Hybrids of sunflower are more stable, highly self-fertile with high seed yield and uniform in maturity (Seetharam, 1979). Thus many hybrids have been under cultivation since the development of first hybrid BSH-1. These hybrids have been developed with the single source of cytoplasm, PET1 which is based on Helianthus petiolaris and this has resulted in narrow genetic base making the crop vulnerable to occurrence of new pests and diseases. Thus, it becomes imperative to look for different CMS and restorer lines which nick well to yield superior hybrids excelling standard checks. At present in Andhra Pradesh, the crop is cultivated in an area of 0.09 lakh ha with an average production of 0.11 lakh tonnes with a productivity of 1222 kg/ha (Directors Report, 2018-19).

Being an exotic crop in India, sunflower crop has narrow genetic base. In the past, substantial efforts have been made to enrich the genetic variability through introduction of exotic accessions at regular intervals that could serve as potential sources of novel genetic variability. However, due to the presence of low genetic variability in the parental lines, the production of superior hybrids in sunflower with desired seed yielding ability has become a serious problem in the present scenario. Besides the knowledge of nature and extent of genetic variation available in the germplasm, the presence of good combining ability in the parental lines for production of potential hybrids over present leading standard hybrids is also crucial. Hence, picking up elite parents with good nicking ability and high per se performance is crucial to obtain high heterotic expression in the hybrids. However, according to Dar et al. (2014) the per se performance is not always a true indicator of potential to exploit the hybrid combinations. Keeping the aforesaid points in view, using Line x Tester mating design (Kempthorne, 1957), an attempt was made in the present investigation to identify general and specific combining abilities of a few promising lines as well as to determine type of gene action controlling agro morphological characters of sunflower.

MATERIALS AND METHODS

Four CMS lines viz., NDLA-3, NDLA-4, CMS-17 A and CMA-30 A were crossed with six restorer lines viz., NO-15, R-106, CPI-1, RHA-271, NGM-16 and NO-30 in a L x T fashion to generate 24 hybrids during rabi 2017-18. The developed hybrids (24) were evaluated along with 10 parents and four standard checks i.e. NDSH-1012, DRSH-1, KBSH-44 and Kaveri during rabi, 2018-19 at RARS, Nandyal in a randomized block design with two replications. Each genotype was raised in two rows in a row length of 3 m with spacing of 60 cm between rows and 30 cm within the row. All the recommended agronomic practices were followed to raise the crop successfully. The observations were recorded by tagging five selected competitive plants randomly in each entry per replication. Observations were recorded on these five plants for plant height (cm), head diameter (cm), number of leaves per plant, stem girth (cm)

Corresponding author's E-mail: varalakshmikumba156@gmail.com;
Regional Agricultural Research Station, ANGRAU, Nandyal-518 501, Andhra Pradesh

and 100 seed weight (g), seed yield per plant (g). The traits, days to 50 % flowering and days to maturity, were recorded on plot basis.

SPAD chlorophyll meter reading was recorded at the time of anthesis with SPAD 502 plus meter for upper, middle and lower leaves and average of them was noted. Leaf area index was calculated by taking fully opened five leaves from each of the five plants at anthesis and area was measured by leaf area meter (LI-3000, Lincoln Nebraska, USA) and was calculated as per the method suggested by Watson (1952).

$$\text{Leaf Area Index} = \frac{\text{Leaf area}}{\text{Ground area}}$$

For deriving Specific leaf area, the dry weight of the same five leaves taken for LAI estimation was used and it was calculated as per the method advocated by Watson (1952).

$$\text{SLA} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Leaf dry weight (g)}}$$

A number of seed traits were estimated by counting total number of filled seeds per head.

Seed set (%) was calculated as:

$$\text{Seed set (\%)} = \frac{\text{Number of filled seeds}}{\text{Number of filled + unfilled seeds}} \times 100$$

Autogamy (%) was calculated as the per cent ratio of seed set under bagging to that of seed set under open pollination.

$$\text{Autogamy (\%)} = \frac{\text{Seed set under bagging}}{\text{Seed set under open pollination}} \times 100$$

Seeds were filled up to the mark in 100 ml beaker and the weight of those seeds was recorded as volume weight in grams.

Hull content was estimated by taking a sample of 100 seeds per genotype and these were de-hulled and estimated as:

$$\text{Hull content (\%)} = \frac{\text{Weight of hull}}{\text{Weight of seeds}} \times 100$$

The seed oil content in per cent was determined directly with Nuclear Magnetic Resonance (NMR) spectrometer available at IIOR, Rajendranagar, Hyderabad.

Oil yield per hectare was calculated as =

$$\frac{\text{Seed yield ((kg/ha) x Oil content (\%)}}{100}$$

The mean values of 18 traits were subjected to line x tester analysis (Kempthorne, 1957) to assess general combining ability (GCA) effects of parents and specific combining ability (SCA) effects of crosses and also nature of gene action detailed by Singh and Chaudhary (2004).

RESULTS AND DISCUSSION

Per se performance: The per se performance of parents for different characters revealed that (Table 1), none of the parents showed desirable high mean performance for all the traits studied. However, among the lines, NDLA-3 registered higher mean values in desirable direction for SPAD chlorophyll meter reading, head diameter, number of seeds per head, seed set per cent, seed yield, hull content and oil yield; NDLA-4 for leaf area index, specific leaf area, plant height, stem girth, number of leaves per plant, days to maturity, volume weight and autogamy per cent; CMS-30 A for plant height, 100 seed weight, seed set per cent and oil content. The line NDLA-4 was desirable for late flowering and maturity and CMS-17 A for early flowering.

Among the testers, NO-30 recorded higher mean values for most of the traits like days to 50 per cent flowering, SPAD chlorophyll meter reading, leaf area index, plant height, stem girth, head diameter, number of leaves per plant, 100-seed weight, seed set per cent, number of seeds per head, seed yield and oil yield, R-106 had desirable mean values for volume weight and oil content, RHA-271 was better for specific leaf area and autogamy per cent, and the tester NGM-16 showed desirable trait with respect to early flowering and maturity.

An examination of mean performance of hybrids showed that none of the hybrids was superior for all the characters. However, the crosses viz., NDLA-4 x NGM-16 for number of seeds per head, oil content and seed yield; CMS-17 A x NO-15 for SPAD chlorophyll meter reading, plant height, 100-seed weight, oil content, oil yield and seed yield; CMS-30 A x NO-15 for volume weight, hull content and number of seeds per head and CMS-30 A x CPI-1 for autogamy and seed set per cent were promising.

Analysis of variance for combining ability: According to Dar et al. (2014) the per se performance is not always a true indicator of its potential to exploit the hybrid combinations. Hence, the means were subjected to line x tester model given by Kempthorne (1957) and detailed by Singh and Chaudhary (2004). The analysis (Table 2) revealed that the mean squares due to lines were significant for leaf area index, plant height, head diameter, number of leaves per plant, number of seeds per head, volume weight, seed yield, hull content, oil content and oil yield while, mean squares of the testers were significant for days to 50% flowering, leaf area index, plant height, head diameter, number of leaves per plant, days to maturity, volume weight, hull content and oil content. The line x tester interactions were significant for days to 50% flowering, SPAD chlorophyll meter reading, leaf area index, specific leaf area, plant height, number of leaves per plant, days to maturity, 100-seed weight, seed set per cent, autogamy per cent and oil content. The means squares with respect to crosses appeared significant for most of the characters except stem girth, indicating the presence of good amount of genetic variability in the experimental material. Similar results have also been reported by Khalid et al. (2017).

GCA and SCA variances: The variances due to specific combining ability (SCA) were higher than general combining ability (GCA) for most of the traits studied except for hull content and head diameter indicating that these traits were influenced by non-additive gene action and can be exploited through heterosis breeding. The existence of non-additive gene action for seed yield, oil content and yield related traits has also been reported by Neelima and Parameshwarappa (2009), Mohanasundaram et al. (2010), Jocic et al. (2012), Jondhale et al. (2012), Patil et al. (2012), Asif et al. (2012), Biradar et al. (2018), Bhoite et al. (2018) and Thorat et al. (2018). However, the contribution of GCA variance appeared to be higher for hull content and head diameter indicating additive gene action played an important role in the inheritance of these traits, where we can go for pedigree breeding followed by selfing to develop superior genotypes in the desired direction. These results were not in line with the findings of Asif et al. (2012), Jondhale et al. (2012), Patil et al. (2012), Shinde et al. (2016), Bhoite et al. (2018) and Thorat et al. (2018).

Contribution of lines, testers and line x tester interactions to total variance: Total variance due to crosses could be partitioned into variance due to lines, testers and their interaction effects (Table 3). The present analysis indicated that the contribution of testers to hybrids was higher than that of lines and it was in agreement with the reports of Shinde et al. (2016) and Bhoite et al. (2018). The contribution of testers was higher in magnitude for volume weight, days to 50 per cent flowering, days to maturity, hull content, seed set per cent, stem girth and 100-seed weight. The same results for the above mentioned traits were also reported by Bhoite et al. (2018). While, the lines were higher in magnitude for oil content, oil yield, plant height, number of leaves per plant, head diameter, number of seeds per head, leaf area index and seed yield. The present results were in consonance with the findings of Jocic et al. (2012), Shinde et al. (2016), Mohyaji et al. (2014) and Kulkarni and Supriya (2017). The high per cent contribution towards total variance due to interaction of line x tester was noticed for specific leaf area, seed set per cent, autogamy per cent, SPAD chlorophyll meter reading, stem girth, 100-seed weight, number of seeds per head and seed yield indicating that interaction of genes in hybrid combination played a major role in the expression of these traits and while it was minor in case of oil content. The results were in line with Devi et al. (2005), Jocic et al. (2012) and Kulkarni and Supriya (2017) for seed yield; Mohyaji et al. (2014) for 100 seed weight and Shinde et al. (2016) for 100 seed weight, number of seeds per head and seed yield.

General combining ability effects: Comparative analysis of the GCA effects of the parents was given in Table 4 and Fig.1. The general combining ability results revealed that none of the lines or testers were found as good general combiners for all the traits (Devi et al. 2005; Chandra et al. 2011; Andarkhor et al. 2013; Memon et al. 2015; Kulkarni and Supriya 2017; Thorat et al. 2018). Among different CMS lines used, the line CMS-30 A was good general combiner as it possessed significantly high GCA effects for most of the traits like leaf area index, plant height, head diameter, number of leaves per plant, days to maturity, 100 seed weight, autogamy per cent, seed yield, hull content, oil content and oil yield and it was a poor combiner for days to 50 per cent flowering, SPAD chlorophyll meter reading, number of seeds per head and volume weight. As regard to pollen parents, NGM-16 was the only parent which showed good combining ability for days to 50 per cent flowering, leaf area index, head diameter, number of leaves per plant, days to maturity and seed yield and it was a poor combiner for SPAD chlorophyll meter reading, specific leaf area, seed set per cent, volume weight, hull content and oil content. The tester NO-15 (leaf area index, 100 seed weight and oil yield), R-106 (volume weight, autogamy per cent, hull content and oil content), CPI-1 (days to maturity, 100-seed weight and seed set per cent) and NO-30 (SPAD chlorophyll meter reading) were observed as good combiners for different traits. However, RHA-271 recorded poor combining ability effects for almost all the traits except days to 50 per cent flowering and days to maturity. The positive and significant GCA effects recorded in the parental lines for different traits was an indication of additive genes controlling their expression and mere hybridization and selection can be exercised for the improvement of traits.

Specific combining ability effects: The SCA effects of hybrids (Table 5) revealed that none of the hybrids possessed high and significant SCA effects for all the traits as reported in other studies (Ahmad et al., 2010; Imran et al., 2015; Shinde et al., 2016; Ingle et al., 2017; Bhoite et al., 2018; Singh and Kumar, 2018). The perusal of SCA effects indicated that, the hybrids viz., NDLA-3 x NO-30 and CMS-17 A x RHA-271 expressed positive SCA effects for seed yield and oil content, respectively with parental combination of low x low GCA effects indicating the role of non-additive gene action for the expression of these traits (Neelima and Parameshwarappa, 2009; Chandra et al., 2011; Patil et al., 2012; Shinde et al., 2016; Bhoite et al., 2018). In these crosses the non-additive type of variation can be exploited by creating multiple crosses and then advanced by selective intermating among desirable segregants. Whereas, the cross CMS-30 A x R-106 also possessed good SCA effects for seed yield with high mean performance and high x low GCA effects of parents (Vairam and Gnanamalar, 2016; Ahmad et al., 2010; Chandra et al., 2011; Andarkhor et al. 2013, Imran et al. 2015, Jondhale et al. 2012, Shinde et al. 2016, Ingle et al. 2017 and Thorat et al. 2018) indicating that among these parents the CMS line contributing positive alleles for high yielding ability and negative alleles by tester. The hybrids NDLA-3 x NO-30 (low x low) and NDLA-4 x NGM-16 (low x high) exhibited high SCA effects and high mean performance for oil yield (Asif et al., 2013; Thorat et al., 2018).

Table 1 Per se performance of 38 genotypes of sunflower for yield and its attributes

Entry	Days to 50 % flowering	SPAD chlorophyll meter reading	Leaf area index	Specific leaf area (cm2/g)	Plant height (cm)	Stem girth (cm)	Head diameter (cm)	Number of leaves per plant	Days to maturity
NDLA-3 X NO-15	54	37.5	8.10	83.22	144	8	18	31	86
NDLA-4 X NO-15	55	36.3	9.25	84.53	155	9	20	39	87
CMS 17A X NO-15	56	40.6	7.65	89.51	179	9	16	38	89
CMS 30A X NO-15	54	35.4	9.55	87.04	181	9	20	39	85
NDLA-3 X R-106	57	40.4	6.40	79.27	160	8	15	32	89
NDLA-4 X R-106	60	37.5	10.00	84.94	186	10	19	38	90
CMS 17A X R-106	56	39.2	8.95	92.10	161	9	17	36	87
CMS 30A X R-106	55	38.0	7.75	78.29	201	10	20	35	85
NDLA-3 X CPI-1	50	38.0	4.85	76.60	139	8	18	24	82
NDLA-4 X CPI-1	52	36.9	6.75	81.14	167	9	18	33	84
CMS 17A X CPI-1	53	38.9	6.90	86.31	159	8	17	32	84
CMS 30A XCPI-1	54	38.5	7.80	91.34	188	9	21	33	85
NDLA-3 X RHA-271	53	39.3	6.75	77.70	154	8	17	30	84
NDLA-4 X RHA-271	54	35.6	8.55	87.30	156	8	17	36	86
CMS 17A X RHA-271	53	39.7	6.55	92.21	154	8	17	37	83
CMS 30A X RHA-271	53	38.0	8.55	95.89	180	9	19	35	83
NDLA-3 X NGM-16	49	40.2	6.95	93.60	143	9	21	30	82
NDLA-4 X NGM-16	54	39.4	9.45	85.21	176	9	20	39	86
CMS 17A X NGM-16	52	37.3	8.10	94.22	143	9	18	39	84
CMS 30A X NGM-16	53	36.8	9.55	89.46	171	9	22	40	85
NDLA-3 X NO-30	55	39.2	8.30	87.60	175	9	19	36	86
NDLA-4 X NO-30	56	39.0	7.75	132.65	189	8	16	38	86
CMS 17A X NO-30	56	41.2	7.30	90.61	181	9	17	34	87
CMS 30A X NO-30	56	42.0	7.75	72.33	206	9	19	38	86
NDSH 1012	53	41.7	7.85	80.13	183	8	20	38	84
DRSH-1	56	37.9	7.60	67.79	192	10	18	33	87
KBSH 44	57	41.4	6.95	75.21	164	9	16	40	89
Kaveri	54	35.5	6.85	82.74	143	8	15	33	86
NO-15	54	33.1	3.30	100.60	109	7	16	30	86
R-106	55	37.0	2.40	113.28	109	6	12	26	88
CPI -1	51	31.6	3.25	116.97	112	7	12	29	82
RHA-271	55	38.5	2.40	150.86	106	6	8	26	87
NGM-16	45	35.1	3.45	126.39	80	6	13	27	79
NO-30	56	41.8	4.10	103.16	147	7	16	36	86
NDLB-3	54	43.0	3.15	130.76	122	8	17	24	86
NDLB-4	60	40.6	3.75	145.49	139	9	15	37	92
CMS- 17B	52	40.4	2.35	135.17	118	8	13	33	88
CMS- 30B	54	41.9	3.60	140.54	165	8	16	34	86
G Mean	54	38.11	6.59	97	156	8	17	34	86
SE (m)	0.29	0.76	0.24	5.40	4.09	0.59	1.16	1.07	0.25
CD (0.05)	0.83	2.19	0.68	15.47	11.71	1.69	3.32	3.07	0.71
CV (%)	0.75	2.84	3.89	7.88	3.70	10.33	9.74	4.52	0.41

Table 2 ANOVA for combining ability for different characters

Source	D. f	Days to 50 % flowering	SPAD chlorophyll Meter reading	Leaf area index	Specific leaf area (cm2/g)	Plant height (cm)	Stem girth (cm)	Head diameter (cm)	Number of leaves per plant	Days to maturity
Replications	1	0.750	0.152	0.270	0.875	165.021	1.688	0.333	0.083	0.333
Crosses	23	10.967**	5.853**	3.017**	255.529**	695.977**	0.883	5.967*	29.435**	8.576**
Lines	3	11.194	10.220	7.992**	238.448	2706.910**	1.132	19.583**	110.167**	7.694
Testers	5	32.400**	7.798	4.673*	172.157	1023.271**	1.488	8.150*	49.100**	20.30**
Line x Tester	15	3.778**	4.331**	1.470**	286.736**	184.693**	0.632	2.517	6.733*	4.844**
Error	23	0.185	1.252	0.150	55.826	26.456	0.601	2.942	2.953	0.073
Gca		0.272	0.058	0.059	-1.181	19.341	0.010	0.131	0.859	0.141
Sca		1.797	1.540	0.660	115.455	79.119	0.016	-0.213	1.890	2.386
gca/sca		0.151	0.038	0.089	-0.010	0.244	0.625	-0.615	0.454	0.059

Source	D. f	100 seed weight (g)	Number of seeds/head	Volume weight (g/100ml)	Seed set (%)	Autogamy (%)	Seed yield (kg/ha)	Hull content (%)	Oil content (%)	Oil yield (kg/ha)
Replications	1	0.025	2310.188	6.750	33.333	20.021	46812.521	5.333	0.104	6840.188
Crosses	23	1.354**	67766.369**	23.272**	75.518**	769.753**	540084.890**	46.257**	11.410**	97586.717**
Lines	3	2.501	186566.299*	18.750*	57.639	1211.354	1359457.91*	108.306**	54.982**	412269.299**
Testers	5	1.965	59329.421	81.750**	129.583	986.388	577981.021	96.933**	13.536**	62839.371
Line x Tester	15	0.921**	46818.699	4.683	61.072**	609.221**	363578.243	16.956	1.986*	46232.649
Error	23	0.296	24093.579	2.402	20.420	139.673	225748.260	15.768	0.682	31154.188
Gca		0.016	792.428	0.703	0.547	6.073	6677.061	1.109	0.357	1942.670
Sca		0.313	11362.560	1.141	20.326	234.774	68914.992	0.594	0.652	7539.231
Gca/Sca		0.051	0.070	0.616	0.027	0.026	0.097	1.867	0.548	0.258

*- Significant at 5 % level; ** - Significant at 1 % level

Table 3 Proportional contributions of lines, testers and line x tester interaction to total variance

Character	Contribution (%)		
	Lines	Testers	Line x Tester
Days to 50 % flowering	13.31	64.22	22.46
SPAD chlorophyll meter reading	22.78	28.96	48.26
Leaf area index	34.56	33.68	31.76
Specific leaf area (cm2/g)	12.17	14.65	73.18
Plant height (cm)	50.73	31.96	17.31
Stem girth (cm)	16.72	36.62	46.67
Head diameter (cm)	42.81	29.69	27.50
Number of leaves per plant	48.82	36.26	14.92
Days to maturity	11.70	51.46	36.84
100 seed weight (g)	24.09	31.56	44.35
Number of seeds/head	35.91	19.03	45.06
Volume weight (g/100ml)	10.51	76.37	13.12
Seed set (%)	9.96	37.30	52.74
Autogamy (%)	20.53	27.86	51.62
Seed yield (kg/ha)	32.83	23.26	43.90
Hull content (%)	30.54	45.55	23.91
Oil content (%)	62.86	25.79	11.35
Oil yield (kg/ha)	55.10	14.00	30.90

Table 4 Estimates of general combining ability (gca) effects of parents for 18 characters

Source	Days to 50 % flowering	SPAD chlorophyll meter reading	Leaf area index	Specific leaf area (cm2/g)	Plant height (cm)	Stem girth (cm)	Head diameter (cm)	Number of leaves per plant	Days to maturity
Lines									
NDLA-3	-1.29 **	0.56	-1.00 **	-5.05 *	-16.19 **	-0.35	-0.29	-4.50 **	-0.54 **
NDLA-4	1.04 **	-1.09 **	0.73 **	4.58 *	2.73	-0.02	-0.04	1.92 **	1.04 **
CMS-17A	0.21	0.94 **	-0.32 **	2.78	-5.85 **	-0.02	-1.38 *	0.92	0.21 *
CMS-30A	0.04	-0.42	0.60 **	-2.32	19.31 **	0.40	1.71 **	1.67 **	-0.71 **
SE (Si)	0.12	0.32	0.11	2.16	1.49	0.22	0.50	0.50	0.08
Testers									
NO-15	0.63 **	-1.06 *	0.74 **	-1.97	-3.60	-0.06	0.25	1.63 *	1.13 **
R-106	2.88 **	0.24	0.38 *	-4.39	8.15 **	0.56	-0.75	0.13	2.25 **
CPI -1	-1.88 **	-0.49	-1.32 **	-4.20	-5.48 **	-0.31	0.00	-4.63 **	-1.63 **
RHA-271	-0.88 **	-0.39	-0.30 *	0.23	-7.48 **	-0.56	-0.63	-0.63	-1.38 **
NGM-16	-2.25 **	-0.12	0.62 **	2.58	-10.60 **	0.44	1.88 **	2.00 **	-1.13 **
NO-30	1.50 **	1.81 **	-0.12	7.75 **	19.02 **	-0.06	-0.75	1.50 *	0.75 **
SE (Sj)	0.15	0.40	0.14	2.64	1.82	0.27	0.61	0.61	0.09

Source	100 seed weight (g)	Seed set (%)	Number of seeds/head	Volume weight (g/100ml)	Autogamy (%)	Hull content (%)	Oil content (%)	Seed yield (kg/ha)	Oil yield (kg/ha)
Lines									
NDLA-3	0.01	-2.79 *	-81.98	-1.38 **	-1.27	1.54	-1.03 **	-239.56	-119.27 *
NDLA-4	-0.58 **	0.88	163.60 **	1.63 **	-11.52 **	-1.13	0.03	180.85	57.90
CMS-17A	0.03	-0.46	-110.90 *	-0.38	-0.19	3.21 *	-1.96 **	-322.81 *	-173.77 **
CMS-30A	0.54 **	2.38	29.27	0.13	12.98 **	-3.63 **	2.97 **	381.52 *	235.15 **
SE (Si)	0.16	1.30	44.81	0.45	3.41	1.15	0.24	137.16	50.95
Testers									
NO-15	0.43 *	-0.96	25.10	0.63	-13.81 **	-0.58	0.43	305.73	120.23*
R-106	-0.86 **	1.67	102.35	5.88 **	11.94 **	-5.33 **	1.84 **	-126.27	15.60
CPI -1	0.43 *	6.67 **	-93.77	-2.38 **	9.44 *	0.92	-1.78 **	-39.40	-64.52
RHA-271	-0.18	-1.08	-14.15	-0.88	-4.56	2.67	-0.39	-155.02	-65.65
NGM-16	0.28	-0.71	81.85	-3.13 **	7.69	4.42 **	-0.93 **	343.73*	86.85
NO-30	-0.11	-5.58 **	-101.40	-0.13	-10.69 *	-2.08	0.83 **	-328.77*	-92.52
SE (Sj)	0.19	1.60	54.88	0.55	4.18	1.40	0.29	167.98	62.40

For the trait, days to 50 per cent flowering, NDLA-3 x NGM-16 was considered as a good specific combiner with significant negative SCA effect and both the parents involved in the cross combination were good general combiners indicating additive gene action (high x high) for the expression of early flowering (Devi et al., 2005; Ahmad et al., 2010; Jondhale et al., 2012; Imran et al., 2015; Azad et al., 2016; Hussain et al., 2017). The cross NDLA-3 x NO-30 had high SCA effect and low x low GCA effects for head diameter (Chandra et al., 2011; Patil et al., 2012; Imran et al., 2015; Patil et al., 2016) indicating non-additive gene action. The parents involved in this cross combination were poor general combiners, but due to high SCA effects this hybrid can be used for yield improvement in future breeding programmes. While, the hybrid NDLA-4 x NGM-16 was a good specific combiner for number of seed per head (Devi et al., 2005; Ahmad et al., 2010; Shinde et al., 2016) with high x high GCA effects.

Table 5 Estimates of specific combining ability (sca) effects of hybrids for 18 characters

Crosses	Days to 50 % flowering	SPAD chlorophyll meter reading	Leaf area index	Specific leaf area (cm2/g)	Plant height (cm)	Stem girth (cm)	Head diameter (cm)	Number of leaves per plant	Days to maturity
NDLA-3 X NO-15	0.54	-0.51	0.47	2.19	-4.56	-0.02	-0.08	-1.38	0.04
NDLA-3 X R- 106	1.29 **	1.04	-0.87 **	0.67	-0.81	-1.15 *	-2.08	1.13	1.92 **
NDLA-3 X CPI-1	-0.96 **	-0.64	-0.72 *	-2.20	-8.19 *	-0.27	-0.33	-1.63	-1.21 **
NDLA-3 X RHA-271	1.04 **	0.61	0.15	-5.53	9.31 *	-0.02	-0.21	-0.13	0.54 **
NDLA-3 X NGM-16	-2.08 **	1.20	-0.56	8.02	0.94	0.48	0.79	-2.25	-1.71 **
NDLA-3 X NO- 30	0.17	-1.69 *	1.53 **	-3.15	3.31	0.98	1.92	4.25 **	0.42 *
NDLA-4 X NO-15	-0.79 *	-0.06	-0.12	-6.13	-12.48 **	0.15	1.17	0.21	-1.04 **
NDLA-4 X R- 106	1.96 **	-0.16	1.00 **	-3.30	6.27	0.52	1.17	0.71	1.33 **
NDLA-4 X CPI-1	-1.29 **	-0.09	-0.55	-7.29	0.90	0.40	-0.08	0.46	-0.79 **
NDLA-4 X RHA-271	-0.29	-1.49	0.22	-5.56	-8.10 *	-0.35	-0.46	-0.54	0.96 **
NDLA-4 X NGM-16	1.08 **	2.10 *	0.21	-9.99	15.02 **	0.15	0.04	-0.17	0.71 **
NDLA-4 X NO- 30	-0.67 *	-0.29	-0.75 *	32.27 **	-1.60	-0.85	-1.83	-0.67	-1.17 **
CMS 17A X NO-15	1.04 **	2.21 *	-0.67 *	0.66	20.10 **	0.15	-1.00	0.71	2.29 **
CMS 17AX R- 106	-1.21 **	-0.54	1.00 **	5.67	-10.15 *	0.02	0.50	-0.29	-0.83 **
CMS 17A X CPI-1	0.54	-0.11	0.65 *	-0.32	1.48	-0.10	-0.25	0.46	0.04
CMS 17A X RHA-271	-0.46	0.64	-0.73 *	1.15	-1.02	0.15	0.88	1.46	-1.21 **
CMS 17A X NGM-16	-0.08	-2.08 *	-0.09	0.81	-9.40 *	-0.35	-0.63	0.83	-0.46 *
CMS 17AX NO- 30	0.17	-0.11	-0.15	-7.97	-1.02	0.15	0.50	-3.17 *	0.17
CMS 30A X NO-15	-0.79 *	-1.63	0.32	3.28	-3.06	-0.27	-0.08	0.46	-1.29 **
CMS 30AX R- 106	-2.04 **	-0.33	-1.12 **	-3.04	4.69	0.60	0.42	-1.54	-2.42 **
CMS 30A X CPI-1	1.71 **	0.84	0.63 *	9.81	5.81	-0.02	0.67	0.71	1.96 **
CMS 30A X RHA-271	-0.29	0.24	0.35	9.93	-0.19	0.23	-0.21	-0.79	-0.29
CMS 30A X NGM-16	1.08 **	-1.22	0.44	1.16	-6.56	-0.27	-0.21	1.58	1.46 **
CMS 30A X NO- 30	0.33	2.09 *	-0.62 *	-21.15 **	-0.69	-0.27	-0.58	-0.42	0.58 **
SE (Sij)	0.30	0.79	0.27	5.28	3.64	0.55	1.21	1.22	0.19

Crosses	100 seed weight (g)	Number of seeds/head	Volume weight (g/100ml)	Seed set (%)	Autogamy (%)	Seed yield (kg/ha)	Hull content (%)	Oil content (%)	Oil yield (kg/ha)
NDLA-3 X NO-15	0.14	-38.77	0.38	5.79	-0.85	-30.31	1.58	-0.12	-14.98
NDLA-3 X R- 106	-0.67	-102.52	-1.88	-8.33 *	25.40 **	-616.81	-1.67	1.03	-202.35
NDLA-3 X CPI-1	-0.41	-34.40	-0.63	-8.33 *	1.40	-333.19	-3.92	-0.98	-126.73
NDLA-3 X RHA-271	0.41	50.98	2.88 *	5.92	-0.10	268.44	-1.17	0.11	100.90
NDLA-3 X NGM-16	0.69	-101.52	-0.88	0.54	-1.35	107.69	1.08	-0.76	12.40
NDLA-3 X NO- 30	-0.17	226.23	0.13	4.42	-24.48 **	604.19	4.08	0.72	230.77
NDLA-4 X NO-15	0.43	-6.35	-1.63	2.63	2.40	327.27	4.75	-0.63	92.85
NDLA-4 X R- 106	0.46	-26.60	2.13	4.00	-30.35 **	96.77	-0.50	0.39	50.98
NDLA-4 X CPI-1	0.53	-39.98	0.38	3.00	-13.35	218.40	0.25	0.65	90.60
NDLA-4 X RHA-271	-0.51	-52.10	-1.13	-6.25	13.65	-452.98	-0.50	-0.12	-157.27
NDLA-4 X NGM-16	-0.67	319.40 **	0.13	2.38	4.90	483.27	-2.25	0.58	189.73
NDLA-4 X NO- 30	-0.24	-194.35	0.13	-5.75	22.77 *	-672.73	-1.75	-0.86	-266.90 *
CMS 17A X NO-15	0.77	-125.85	1.38	-4.04	1.56	-62.56	-4.08	1.21	14.02
CMS 17AX R- 106	-0.34	55.90	-1.88	1.33	7.31	-24.06	1.17	-0.54	-28.35
CMS 17A X CPI-1	0.37	24.02	-0.63	1.83	-5.19	213.06	2.42	-0.84	45.77
CMS 17A X RHA-271	-0.12	1.40	-0.13	-2.92	0.31	4.69	2.67	1.25 *	39.40
CMS 17A X NGM-16	-0.58	45.40	1.13	2.71	11.56	-77.56	1.42	-0.77	-51.60
CMS 17AX NO- 30	-0.09	-0.85	0.13	1.08	-15.56	-53.56	-3.58	-0.30	-19.23
CMS 30A X NO-15	-1.34 **	170.98	-0.13	-4.38	-3.10	-234.40	-2.25	-0.45	-91.90
CMS 30AX R- 106	0.55	73.23	1.63	3.00	-2.35	544.10	1.00	-0.88	179.73
CMS 30A X CPI-1	-0.49	50.35	0.88	3.50	17.15	-98.27	1.25	1.17	-9.65
CMS 30A X RHA-271	0.22	-0.27	-1.63	3.25	-13.85	179.85	-1.00	-1.24 *	16.98
CMS 30A X NGM-16	0.56	-263.27 *	-0.38	-5.63	-15.10	-513.40	-0.25	0.95	-150.52
CMS 30A X NO- 30	0.50	-31.02	-0.38	0.25	17.27	122.10	1.25	0.44	55.35
SE (Sij)	0.38	109.76	1.10	3.20	8.36	335.97	2.81	0.58	124.81

*- Significant at 5% level ** - Significant at 1% level

Table 6 Selected crosses with high sca effects, gca status of parents and mean performance with respect to yield and yield component

Character	Crosses with high sca effect	sca effects	gca status of parents		Mean performance
			Female	Male	
Days to 50 % flowering	NDLA-3 x NGM-16	-2.08 **	H	H	48.5
	CMS-30 A x R- 106	-2.04 **	L	L	55.0
SPAD	CMS-17 A x NO-15	2.21 *	H	L	40.6
	NDLA-4 x NGM-16	2.10 *	L	L	39.4
	CMS-30 A x NO- 30	2.09 *	L	H	42.0
Leaf area index	NDLA-3 x NO- 30	1.53 **	L	L	8.30
	NDLA-4 x R- 106	1.00 **	H	L	10.0
	CMS-17 A x R- 106	1.00 **	L	L	8.95
Specific leaf area (cm2/g)	CMS-30 A x NO- 30	-21.15**	L	H	132.65
Plant height (cm)	CMS-17 A x NO-15	20.10 **	L	L	179.00
	NDLA-4 x NGM-16	15.02 **	L	L	175.50
Stem girth (cm)	CMS-30 A x R- 106	0.60	H	H	10
	NDLA-4 x R- 106	0.52	L	H	10
Head diameter (cm)	NDLA-3 x NO- 30	1.92	L	L	19
	NDLA-4 x NO-15	1.17	L	L	20
Number of leaves per plant	NDLA-3 x NO- 30	4.25 **	L	H	36
Days to maturity	CMS-30 A x R- 106	-2.42 **	H	L	55
100 seed weight (g)	CMS-17 A x NO-15	0.77	L	H	7.00
	NDLA-3 x NGM-16	0.69	L	H	6.75
Number of seeds/head	NDLA-4 x NGM-16	319.40 **	H	H	1564
Seed set (%)	NDLA-3 x RHA-271	5.92	L	L	79
	NDLA-3 x NO-15	5.79	L	L	79
Volume weight (g/100ml)	NDLA-3 x RHA-271	2.88 *	L	L	45
Autogamy (%)	NDLA-3 x R- 106	25.40 **	L	H	105
	NDLA-4 x NO- 30	22.77 *	L	L	40
Hull content (%)	CMS-17 A X NO-15	-4.08	L	L	40
	NDLA-3 x CPI-1	-3.92	L	L	40
	CMS-17 A x NO- 30	-3.58	L	H	39
Oil content (%)	CMS-17 A x RHA-271	1.25 *	L	L	33.78
Seed yield (kg/ha)	NDLA-3 x NO- 30	604.19	L	L	3194
	CMS-30 A x R- 106	544.10	H	L	3958
Oil yield (kg/ha)	NDLA-3 x NO- 30	230.77	L	L	1125
	NDLA-4 x NGM-16	189.73	L	H	1440

*- Significant at 5 % level; **- Significant at 1 % level

NDLA-3 x RHA-271 and NDLA-3 x R-106 were good specific combiners for seed set and autogamy per cent respectively, with low x low (Jondhale et al., 2012; Patil et al., 2012; Thorat et al., 2018) and low x high GCA effects of parents, individually. The cross combinations CMS-17 A x NO-15 (low x high) and NDLA-3 x RHA-271 (low x low) were having good specific combining ability with high SCA effects for 100-seed weight (Jondhale et al., 2012; Patil et al., 2012; Thorat et al., 2018) and volume weight (Patil et al., 2012; Shinde et al., 2016; Biradar et al., 2018), respectively.

The hybrids viz., NDLA-3 x NO-30 (seed yield, oil yield, head diameter and leaf area index); CMS-17 A x RHA-271 (oil content); NDLA-4 x NO-30 (autogamy per cent); NDLA-3 x RHA -271 (volume weight) and CMS-30 A x R-106 (days to 50 per cent flowering) were having poor GCA effects (low x low), even though they expressed high SCA effects due to cancelation of the undesirable effects. In such combinations, to obtain better segregants, selection may be postponed to later generations to develop high yielding hybrids. While, the crosses CMS-30 A x R-016 (seed yield and days to maturity), CMS-17A x NO-15 and NDLA-3 x NGM-16 (100 seed weight), NDLA-3 x R-106 (autogamy per cent) and CMS-17 A x NO-30 (hull content) were having one good general combiner and the other as poor combiner, but they exhibited good specific combining ability due to accumulation of favourable genes and partly due to dominance interaction. The selected hybrids revealing significant SCA effects in most of the cases did not arise as a result of both the parents having high GCA effects (Table 5). But occurred as a result of crosses between parents with low x low, high x low or low x high GCA effects for majority of the traits.

The present study indicated that most of the traits exhibited significant differences among lines, testers and line x tester interactions and controlled by non-additive type of gene action except hull content and head diameter which have additive gene action. The line CMS- 30A and tester NGM-16 had maximum desirable GCA effects for majority of the traits so these parents can be preferred in future breeding programmes for development of superior hybrids. Similarly, NDLA-3 x NO- 30 for seed yield and CMS 17 A x RHA-271 for oil content were observed as potential crosses having desirable SCA values and can be commercially exploited.

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Linseed breeding for early maturing and dual-purpose genotypes in North-Western Himalayas

ASHITA BISHT AND SATISH PAUL

College of Agriculture, CSKHPKV, Palampur-176 062, Himachal Pradesh

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ABSTRACT

Performance of linseed genotypes and hybrids in a series of crosses following line × tester mating design was studied for 13 agro-morphological traits involving parents having fibre, seed and dual-types. A total of 15 lines (7 indigenous and 8 exotic) and three well-adapted, early maturing indigenous testers were used for generation of new variability. Although both additive and non-additive gene effects were significant, the non-additive gene action coupled with the presence of low heritability predominated for all the traits. Genotypes Baner, Belinka and JLS-73 were the most promising parents. The highest value of heterobeltiosis and standard heterosis was observed for seed yield (226.62%) and primary branches (263.66%) per plant respectively. Based on per se performance, SCA effects and extent of heterosis the cross-combination KL-284 × JLS-73 was the most promising for dual-purpose. However, for earliness and other seed yield and related traits Ottawa × RLC-133 was the most promising hybrid. So, these potential hybrids could be further utilized in breeding for development of new varieties.

Keywords: Combining ability, Gene action, Heterosis, Line × tester, Linseed

Linseed (Linum usitatissimum L.) is chiefly cultivated for its fibre and oil. When grown for fibre it is known as 'flax', if grown for seed oil it is called 'linseed' but when it is cultivated for or both fibre, and oil it is called 'dual-purpose flax'. Its oil has great potential in industries like paints, printing inks, varnishes, resins enamels, stickers, tarpaulins and soaps. Its oil is a rich source of omega-3 and omega-6 fatty acids while the fibre with excellent strength and durability is used to produce high-quality linen (Sood et al., 2007; Sood et al., 2011).

The current worldwide acreage of linseed is 2.78 million hectares with a total annual production of 2.88 million tonnes and productivity of 3651.60 kg/ha. India holds fifth rank in area with 300 thousand hectares with annual production of 184 thousand tonnes and productivity of 613.30/kg ha. It contributes about 10.80 per cent and 6.58 per cent to world total area and production, respectively (FAO Stat, 2019). Due to its autogamous nature, the crop suffers from a narrow genetic base of released varieties. Therefore, continuous breeding endeavours are necessary to develop varieties involving distant and exotic germplasm, particularly from primary centres of origin (South West Asia and Mediterranean region for oil and fibre type respectively, Vavilov, 1951) to increase productivity. Moreover, genetic variability created by the inclusion of diverse germplasm for important characters is most crucial for effective selection and serves as a basis of hybridization. Most of the investigations have concentrated on improving either oil or fibre content (Bhateria et al., 2006; Kumar and Paul, 2015; Kumar et al., 2016). Therefore, present study has tried to include traits related to oil and fibre as well as the characters associated with early maturity.

The line × tester analysis (Kempthorne, 1957) was used to assess parents of indigenous and exotic backgrounds comprising of all three types (fibre, oil and dual-types) with medium maturing lines and early maturity testers. Line x tester method provides robust information on combining ability analysis (Sprague and Tatum, 1942) to determine the nature and magnitude of gene action involved in the manifestation of economically important traits. The phenomenon of heterosis by crossing two inbreds can also be estimated through this analysis (Hallauer and Miranda, 1998). Ultimately this study aimed to evaluate the combining ability, heterosis and generate new variability which could act as a repository for superior recombinants by establishment of new lines with improved traits and choosing appropriate breeding procedure.

MATERIALS AND METHODS

Genetic material and planting design: The material consisted of 15 diverse lines, comprising of eight exotic and seven indigenous. In addition, three well adapted and early maturing indigenous genotypes were used as testers having varied parentage/source (Table 1) which was evident from their distinct flower morphology (Fig. 1). During crop season 2015-16, staggered sowing of lines and testers was done to ensure proper synchronization of flowering time between the two. The lines were sown in October 2015, while the testers were sown in November 2015 to develop 45 cross combinations in accordance to line × tester approach. Further unpaired planting arrangement was followed with three replications of each genotype. In the crop season 2016-17, a total of 63 entries (18 parents + 45 F1s) were sown in the month of October 2016 in complete randomized block design with three replications. In each replication entries, parents and F1s were grown in single row plot of 1.5 m length with the row to row and plant to plant spacing of 30 cm and 10 cm, respectively. Recommended package of practices was adopted.

Experimental site: The trial was conducted at the Experimental Farm of Department of Crop Improvement, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya (CSKHPKV) situated at 32°80'N latitude and 76°33'E longitude at an altitude of 1290.80 meters above mean sea level in mid-hills of North-Western Himalayas. Agro-climatically, it represents the sub-temperate humid zone with annual rainfall varying from 1500 to 2500 mm. The mean weekly meteorological observations of the two crop seasons were recorded at Agrometeorology Observatory, Department of Agronomy, Forages and Grassland Management, CSKHPV, Palampur; this data is also available online at www.cropweatheroutlook.in.

Data recording and statistical analysis: Agro-morphological data were recorded for each genotype across all replicates for plant height (PH, cm), technical height (TH, cm), primary branches/plant (PB), secondary branches/plant (SB), number of capsules/plant (CP), number of seeds/capsule (SC), days to seed fill (DS), aerial biomass (AB, g), seed yield/plant (SY, g), harvest index (HI, %) and 1000-seed weight (SW, g) except for phonological characters i.e. days to flowering (DF, 50%) and maturity (DM, 75%) where data were recorded on plot basis. The data were subjected to analysis of variance (ANOVA) by fixed effects statistical model using TNAUSTAT (Manivannan 2014) and further re-evaluated using OPSTAT (Sheoran et al. 1998). Analysis of variance for combing ability was determined in accordance with the method given by Kempthorne (1957).

Per cent contribution of lines, testers, and their interactions were computed as per the formulae suggested by Singh and Chaudhary (1977): Per cent contribution of lines = SS (lines)/SS (crosses) × 100; Per cent contribution of testers = SS (testers) / SS (crosses) × 100; Per cent contribution of lines × testers = SS (lines × testers)/ SS (crosses) × 100 where: SS = sum of squares.

Heritability in the narrow sense (h^{2n}_{s}) was calculated according to Singh and Chaudhary (1977):

$$h^{2n}_{s} = \sigma^2A/ \sigma^2p$$

where: σ^2A = additive variance; σ^2p = phenotypic variance The magnitude of heritability was classified as high (>50%), moderate (30%-50%) and low (<30%) as per Bhateria et al. (2006).

RESULTS AND DISCUSSION

Analysis of variance for combining ability effects: Analysis of variance (ANOVA) for GCA in both lines and testers showed highly significant differences (P ? 0.05) for all the traits except SY and SW in case of testers (Table 2). It revealed additive gene effects manifested in these traits and selection of good general combiners (Table 3) could be used as potential parents in future hybridization programs. The SCA effects were also highly significant (P ? 0.01) indicating the presence of non-additive gene effects which could be harnessed through hybridization. This suggested the contribution of both additive and non-additive genetic components towards the variability in these traits (Bhateria et al. 2006, Sood et al. 2007). The traits like DF, DM and SF were important indicator of earliness, and therefore, significant GCA and SCA effect in the negative direction was considered desirable while for other traits significant effect in a positive direction was considered necessary. Analysis also indicated that the traits PH, TH and AB contributed for fibre, while PB, SB, CP, SC, SY, SW and HI contributed for seed oil. The parent which showed significant GCA value in desirable direction was termed as a good combiner. On the contrary, the parent which showed significant GCA value in the opposite direction was termed as a poor combiner and the ones that did not show significant GCA value in either direction were termed as average combiners. However, none of the parents or cross combinations possessed desirable GCA and SCA effects for all the characters (Supplementary material Appendix-C and D). Nevertheless, lines Baner and Belinka, and tester JLS-73 were good general combiners for most of the traits (Table 3). Furthermore, two cross combinations viz., KL-284 × JLS-73, and Belinka × RLC-133, were found promising for earliness, and dual-purpose, while crosses SLS-V × JRF-4 and Rajeena × JLS-73 were specific combiners for most of the traits.

Based on the above criteria when parents having good, average and low GCA effects were hybridized to develop crosses with high SCA effects, no specific pattern was displayed (Table 4). This observation suggested incongruity of SCA effects of hybrids with the GCA effects of parents (Bhateria et al., 2006). The high SCA effects among crosses involving all the three kinds of parents can be explained by higher levels of epistatic interactions among the genotypes. Crosses having high SCA effects involving parents with good × good GCA effects could be resultant of higher-order additive interactions, which is fixable in nature. However, when high SCA effects were observed in good × poor general combiners it was the effect of desirable additive effects of the good general combiner and epistatic effect of the poor general combiner, which are of non-fixable nature. At last, when crosses involving poor × poor general combiners produced high SCA this can be assigned to dominance × dominance type of non-allelic gene interaction producing overdominance, which again has a disposition towards non-fixable gene action (Bhateria et al., 2006).

Estimates of genetic components of variance: The higher magnitude of specific combining ability variance (?2SCA) than that of general combining ability variance (?2GCA) for all the characters (Table 4), suggested that non-additive gene action predominately governed these traits. The ratio of ?2A/?2D was found to be less than unity which further indicated the active involvement of non-additive gene action. These results are supported by the average degree of dominance, which indicated the presence of overdominance (>1) for the inheritance of all the traits under study as reported by others (Tewari et al., 2004; Singh et al., 2014; Kumar and Paul 2015; Kumar et al. 2016; Singh et al. 2016). The narrow sense heritability (h2ns) estimates showed low heritability for all the traits (Bhateria et al., 2006; Kumar and Paul 2015). This elucidated the presence non-fixable component of variation among these characters. As non-additive gene action with low heritability was involved, such crosses might not be of direct use but selection from the segregating generations derived from such crosses might be will be effective. Low heritability would also enable the use of heterosis which could be achieved by crossing divergent lines like in biparental mating.

Table 1 List of linseed accessions and their parentage/source used in the study

Accession	Parentage/Source	Type	Maturity type	Days to maturity
Lines				
SLS-V	JNKVV, Madhya Pradesh (India)	Fibre type	Medium	202.00
K-1 (Raja)	CSIRO, Canberra (Australia)	Fibre type	Medium	202.00
Ottawa	CSIRO, Canberra (Australia)	Fibre type	Medium	201.33
B-14 × Burke	CSIRO, Canberra (Australia)	Fibre type	Medium	200.67
Wilden	CSIRO, Canberra (Australia)	Fibre type	Medium	200.67
Birio	CSIRO, Canberra (Australia)	Fibre type	Medium	200.67
Barnes	CSIRO, Canberra (Australia)	Fibre type	Medium	200.67
Rajeena	CSIRO, Canberra (Australia)	Fibre type	Medium	200.67
Belinka	CSIRO, Canberra (Australia)	Fibre type	Medium	200.67
KL-284	Rajeena × Him Asi-2 (India)	Fibre type	Medium	200.67
Baner	EC-21741 × LC-214 (India)	Seed type	Medium	200.67
Bhagsu	RL-50-3 × Surbhi (India)	Seed type	Medium	200.67
Himani	DPL-20 × KLS-1 (India)	Seed type	Medium	200.67
Him Alsi-2	EC-21741 × LC-216 (India)	Dual purpose	Medium	200.67
Nagarkota	New River × LC-216 (India)	Dual purpose	Medium	200.67
Testers				
JRF-4	CRIJAF, Madhya Pradesh (India)	Fibre type	Early	162.33
JLS-73	JNKVV, Madhya Pradesh (India)	Seed type	Early	150.67
RLC-133	IGKV, Chhattisgarh (India)	Seed type	Early	160.00

[CRIJAF: Central Research Institute for Jute and Allied Fibres, CSIRO: Commonwealth Scientific and Industrial Research Organisation, IGKV: Indira Gandhi Agricultural University, JNKVV: Jawaharlal Nehru Krishi Vishwa Vidyalaya; a: Standard check]

Table 2 Analysis of variance for combining ability effects for various characters in linseed

Sources	Lines	Testers	Lines vs. Testers	Error
df	14	2	28	88
Characters				
DF	358.39**	50.81**	164.85**	0.90
DM	662.96**	10.72**	29.80**	0.93
DS	345.45**	33.03**	118.21**	2.10
PH (cm)	635.62**	45.00**	337.61**	9.30
TH (cm)	315.91**	106.21**	133.69**	19.12
AB (g)	72.66**	17.60**	25.37**	0.20
PB	273.01**	261.07**	71.36**	1.11
SB	82.11**	99.95**	24.50**	0.30
CP	4903.56**	1613.73**	1813.50**	21.53
SC	10.66**	5.06*	5. 84**	0.26
SY (g)	6.42**	1.02	2.38**	0.03
SW (g)	5.64**	0.53	2.16**	0.32
HI (%)	47.05**	4.22*	45.08**	2.26

[* Significant at P ? 0.05, ** Significant at P ? 0.01]

Table 3 Top ranking parents and cross combinations based on their GCA and SCA estimates

Characters	Parents	Estimates of GCA effects	Crosses	Estimates of SCA effects	GCA effects of the parents
DF	Bhagsu	-17.74**	Nagarkot × JRF-4	-9.97**	Poor × Poor
	Baner	-7.19**	(B-14 × Burke) × JLS-73	-9.46**	Good × Good
	KL-284	-2.96**	Ottawa × JLS-73	-9.08**	Poor × Good
DM	Bhagsu	-22.86**	SLS-V × JRF-4	-5.90**	Poor × Poor
	Baner	-13.64**	Wilden × RLC-133	-4.85**	Poor × Good
	Him Alsi-2	-5.64**	Birio × RLC-133	-4.81**	Poor × Good
DS	Himani	-10.67**	Barnes × JLS-73	-14.10**	Poor × Poor
	Him Alsi-2	-9.45**	Nagarkot × RLC-133	-13.73**	Good × Good
	Nagarkot	-6.56**	Bhagsu × JRF-4	-7.95**	Good × Average
PH (cm)	Baner	13.08**	Rajeena × JLS-73	23.75**	Average × Poor
	Ottawa	12.57**	KL-284 × JLS-73	19.72**	Poor × Poor
	B-14 × Burke	10.10**	SLS-V × JRF-4	16.70**	Poor × Good
TH (cm)	Himani	14.56**	Rajeena × RLC-133	13.25**	Average × Poor
	B-14 × Burke	7.87**	KL-284 × JLS-73	12.80**	Poor × Average
	Ottawa	5.01**	Rajeena × JLS-73	11.20**	Average × Average
AB (g)	Baner	5.96**	Ottawa × JLS-73	7.33**	Good × Good
	Birio	4.59**	SLS-V × JRF-4	4.93**	Poor × Poor
	Belinka	3.81**	Belinka × RLC-133	4.22**	Good × Good
PB	Baner	14.22**	K-1 (Raja) × RLC-133	11.04**	Average × Poor
	Belinka	9.95**	Rajeena × JLS-73	8.72**	Good × Good
	Rajeena	4.13**	Himani × RLC-133	6.46**	Poor × Poor
SB	Belinka	7.53**	Baner × JLS-73	5.17**	Good × Good
	Baner	3.92**	Himani × RLC-133	4.31**	Poor × Poor
	Rajeena	2.98**	Ottawa × JLS-73	4.17**	Poor × Good
CP	Baner	53.75**	Ottawa × JLS-73	43.45**	Good × Good
	Belinka	39.37**	Belinka × RLC-133	37.58**	Good × Good
	Rajeena	11.19**	Ottawa × RLC-133	36.01**	Good × Good
SC	SLS-V	2.15**	KL-284 × JLS-73	2.83**	Poor × Good
	Baner	1.30**	Belinka × RLC-133	2.12**	Good × Poor
	Wilden	1.03**	Rajeena × JRF-4	1.54**	Poor × Average
SY(g)	Baner	1.98**	Belinka × RLC-133	1.63**	Good × Average
	Belinka	1.39**	KL-284 × JLS-73	1.61**	Poor × Good
	Birio	0.78**	Ottawa × JLS-73	1.59**	Good × Good
SW (g)	Bhagsu	1.31**	Barnes × RLC-133	1.49**	Good × Average
	Birio	1.00**	Belinka × RLC-133	0.96**	Good × Average
	KL-284	0.84**	Baner × JLS-73	0.92**	Average × Average
HI (%)	Barnes	3.24**	Him Alsi-2 × JRF-4	6.62**	Good × Average
	Belinka	2.99**	Birio × JRF-4	5.83**	Poor × Average
	Baner	2.54**	KL-284 × JRF-4	5.01**	Average × Average

[** Significant at P ? 0.01]

Table 4 Estimates of genetic components of variance for different characters

Characters	σ2GCA	σ2SCA	σ2A	σ2D	σ2A/σ2D	Average degree of dominance	Heritability (%)	Contribution (%)		
			F = 1	F = 1		$\sqrt{\sigma^2 D/\sigma^2 A}$	h2ns	Lines	Testers	Interaction
DF	0.72	54.65	1.44	53.65	0.03	6.10	1.59	51.54	1.04	47.41
DM	2.56	9.62	5.11	9.62	0.53	1.37	3.84	91.56	0.21	8.23
PH (cm)	1.04	109.44	2.08	109.44	0.02	7.25	0.47	48.25	0.49	51.26
TH (cm)	0.72	38.19	1.44	38.19	0.04	5.15	1.12	52.79	2.54	44.68
PB	0.93	23.42	1.85	23.42	0.08	3.56	4.79	60.26	8.23	31.50
SB	0.28	8.07	0.55	8.07	0.07	3.83	4.29	56.48	9.82	33.70
CP	12.40	597.32	24.80	597.32	0.04	4.91	2.85	55.97	2.63	41.40
SC	0.02	1.86	0.04	1.86	0.02	6.82	1.39	46.25	3.14	50.62
DS	0.87	38.70	1.74	38.70	0.04	4.72	2.44	58.89	0.80	40.30
AB (g)	0.18	8.39	0.37	8.39	0.04	4.76	3.50	57.70	2.00	40.30
SY(g)	0.02	0.78	0.03	0.78	0.04	4.83	2.84	56.73	1.28	41.99
SW (g)	0.01	0.61	0.03	0.61	0.05	4.51	2.28	56.22	0.75	43.03
HI (%)	0.22	8.01	0.45	8.01	0.06	4.24	2.16	34.14	0.44	65.42

[F: Inbreeding coefficient]

Table 5 Top ranking cross combinations based on heteriobeltiosis (%) and standard heterosis (%) for different characters

Character	Superior cross over better parent	H1 (%)	Superior cross over standard check	H2 (%)
DF	Wilden × RLC-133, Birio × RLC-133	-8.33	Wilden × RLC-133, Birio RLC-133	-19.71
			Ottawa × RLC-133	-9.49
			KL-284 × JRF-4, Baner × JRF-4, Nagarkot × JRF-4, SLS-V × RLC-133, K-1 (Raja) × RLC-133, (B-14 × Burke) × RLC-133, Baner × RLC-133, Himani × RLC-133, Him Alsi-2 × RLC-133	-6.81
DM	-		Wilden × RLC-133, Birio × RLC-133	-16.28
			K-1 (Raja) × JLS-73	-9.64
			Ottawa × RLC-133, (B-14 × Burke) × RLC-133	-9.14
DS	-		Nagarkot × RLC-133	-35.94
			Bhagsu × RLC-133	-25.00
			Belinka × RLC-133	-23.44
PH (cm)	Bhagsu × JLS-73	6.66	K-1 (Raja) × JLS-73	13.50
		9.46	Rajeena × JLS-73	12.55
			Baner × JLS-73	10.60
TH (cm)	-		Rajeena × RLC-133	75.71
			Barnes × RLC-133	32.18
			KL-284 × JRF-4	30.43
AB (g)	Ottawa × RLC-133	105.81	Ottawa × JLS-73	99.34
	Ottawa × JLS-73	48.75	KL-284 × JLS-73	50.61
	Ottawa × JRF-4	47.85	Ottawa × RLC-133	48.73
PB	K-1 (Raja) × RLC-133	192.17	K-1 (Raja) × RLC-133	263.66
	Ottawa × RLC-133	100.08	Rajeena × JLS-73	149.59
	Rajeena × JLS-73	62.75	Baner × JLS-73	147.75
SB	KL-284 × JLS-73	73.42	Baner × JLS-73	178.59
	Baner × RLC-133	61.76	Rajeena × JLS-73	105.13
	Himani × RLC-133	51.81	KL-284 × JLS-73	104.23
CP	Baner × JLS-73	88.00	Ottawa × RLC-133	51.52
	Belinka × RLC-133	85.02	KL-284 × JLS-73	24.11
	Ottawa × RLC-133	79.53	Ottawa × JLS-73	14.21
SC	K-1 (Raja) × RLC-133	107.28	KL-284 × JLS-73	28.19
	K-1 (Raja) × JLS-73	48.65	K-1 (Raja) × JRF-4	25.49
	K-1 (Raja) × JRF-4	44.84	K-1 (Raja) × RLC-133	22.18
SY (g)	Ottawa × RLC-133	226.62	KL-284 × JLS-73	49.28
	Baner × JLS-73	116.74	Ottawa × RLC-133	44.96
	Ottawa × JLS-73	99.16	Ottawa × JLS-73	37.18
SW (g)	Belinka × JLS-73	29.79	Birio × RLC-133	18.25
	Ottawa × JLS-73	24.22	Baner × JLS-73	13.15
	K-1 (Raja) × JLS-73	23.73	KL-284 × JLS-73, Nagarkot × JLS-73	12.16
HI (%)	Baner × JLS-73	42.05		
	Ottawa × RLC-133	33.07		
	Belinka × JLS-73	29.56		

[H1: Heteriobeltiosis, H2: Standard heterosis]

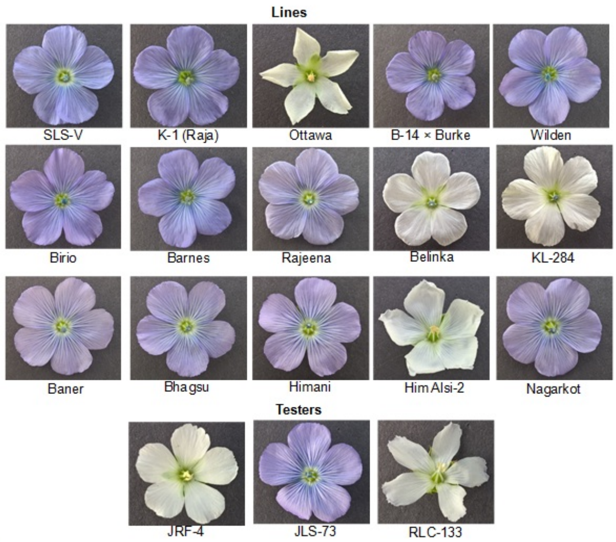

Figure 1. Parents showing distinct flower morphology

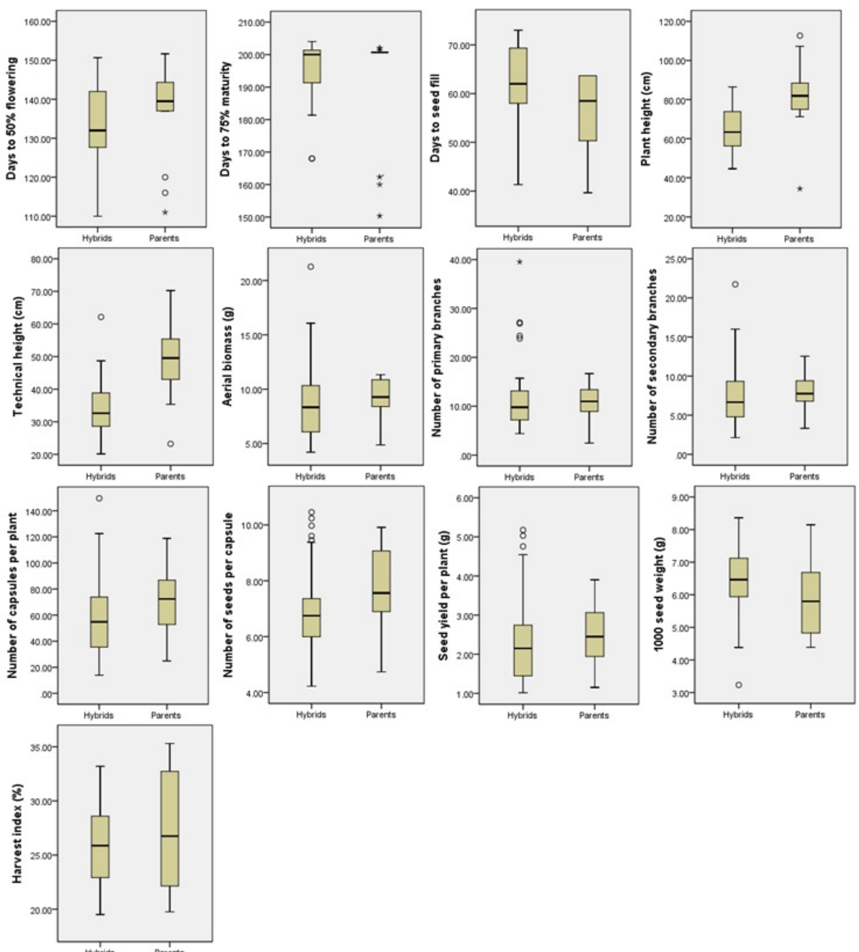

Fig. 2. Box plot depicting linseed population of 45 hybrids and their 18 parents evaluated for 13 agro-morphological characters

The contribution of lines was highest to total variation for most of the traits, except for SC and HI, which was higher for line × tester interaction. The maximum and minimum contribution of lines was observed for DM (91.56%) and HI (34.14%) respectively. Perusal of Table 4, also reveal that the testers contributed negligibly for all the traits (Bhateria et al., 2001; Bhateria et al., 2006), the maximum contribution was recorded for SB (9.82%) and minimum for DM (0.21%). The highest contribution by line × tester interaction was for HI (65.42%) and lowest for DM (8.23%).

Means, heterobeltiosis and standard heterosis: The mean values play a key role in the determination of heterosis. Overall, the mean values of parents and hybrids showed significant differences (P ? 0.05) for all the traits (Supplementary material Appendix-A and B). The parents were superior for all the characters except for AB and HI in comparison to standard check. A similar trend was also observed for hybrids which were superior for all the characters except for HI on per se performance. In general, the crosses showed a wider range than parents for most of the traits except for DF and DM, where the parents, specifically testers were superior (Fig. 3).

Estimates of heterosis over better parent (H1) and standard check here, Nagarkot (H2) revealed significant heterotic value for all the characters except for HI (Supplementary material Appendix-F). Top ranking superior cross combinations which excelled either over superior parent or standard check have been summarized in Table 5 with their respective heterotic values. The maximum value of heterobeltiosis was observed for SY (226.62%) followed by PB (192.17%) which corresponded to the maximum numbers of outliers in desirable direction for these traits (Figure. 3). In the case of standard heterosis, the maximum value was observed for PB (263.66%) followed by SB (178.59%, Singh et al., 2005). Heterosis over better parent for most traits was observed in two cross combinations Baner × JLS-73 and Ottawa × RLC-133. It is clear that none of the cross combinations performed better than the standard check Nagarkot for all the traits, nevertheless, the cross KL-284 × JLS-73 was identified as a potential hybrid for dual-purpose while, two crosses K-1 (Raja) × RLC-133, and Ottawa × RLC-133 were promising for earliness as well as dual-purpose from a total of 45 crosses. These crosses could be advanced for fixation of traits for further evaluation of transgressive segregants.

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Sabour Tisi-1: High yielding linseed variety (*Linum usitatissimum* L.) for utera condition suitable for north eastern zone of India

RAM BALAK PRASAD NIRALA*, SHIVASANKAR ACHARYA AND AMARENDRA KUMAR

Bihar Agricultural University, Sabour, Bhagalpur-813 210, Bihar

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ABSTRACT

A pure line variety, Sabour Tisi-1 (BAUP 101) was developed and evaluated in AICRP on linseed trials from 2013-14 to 2015-16. Average seed yield of Sabour Tisi-1 (BAUP101) was 686 kg per ha, which was 27.75% and 142.40% higher yield than the national check, T397 and zonal check, R552, respectively. Similarly, the oil yield was 196 kg per ha which was 20.25% and 80.46% higher oil yield than the national check (T397) and zonal check (R552) respectively. Varietal Identification Committee of ICAR identified Sabour Tisi-1 (BAUP 101) in 2016 for utera condition of zone II of India comprising the states of Bihar, Jharkhand, West Bengal, Assam and Uttar Pradesh excluding Bundelkhand. This variety has been recommended for release and notification (Central Varieties) by Central Sub-Committee on Crop Standards, notification and release of varieties for agricultural Crops, Government of India, Ministry of Agriculture and Farmers Welfare and published in the Gazette of India.

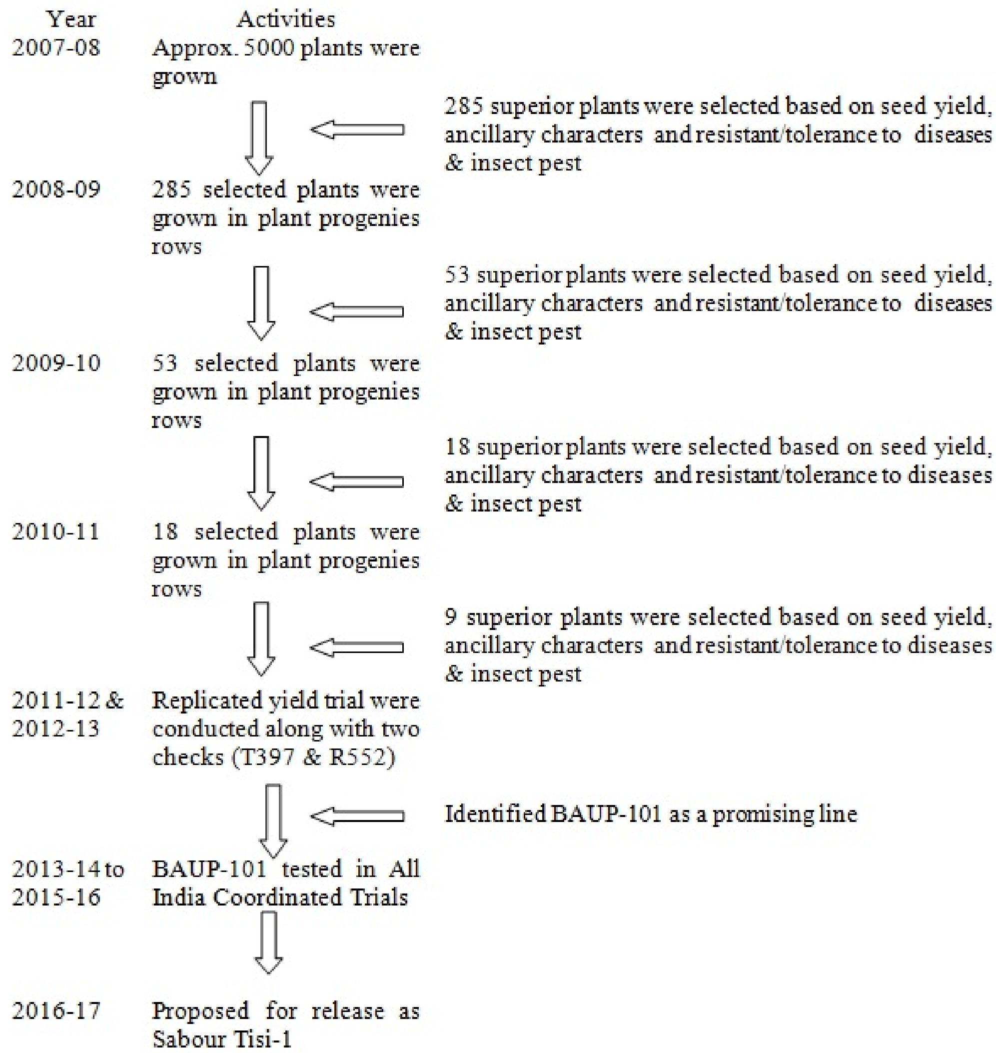
Keywords: Linseed, Oil yield, Sabour Tisi-1, Seed yield, Utera condition

The cultivated area of linseed in India is 293 thousand hectares with production and productivity of 125 thousand tons and 427 kg/ha, respectively (FAOSTAT, 2018). In India, linseed is being cultivated under three conditions viz; irrigated, rainfed and utera conditions. In utera condition seeds of linseed are broadcasted in standing rice crop before one week of harvesting of rice with sufficient moisture in the field. It reduces cost of cultivation and irrigation, and provides opportunity for timely sowing. The nine linseed varieties viz; LC-185, Jawahar-7, Shurbhi, Baner (KL-224), Himani (KL-214), Bhagsu (KL-215), RLC-138, Utera Alsi (RLC-143) and Sabour Tisi-1 have been released and notified in India for Utera condition during 1975 to 1918. Of them, LC-185 has an average yield of 500 kg/ha and oil content 38.89%, and recommended for the state of Punjab in 1975. Jawahar-7 has average yield 300 kg/ha and oil content 37.79 %, and recommended for the state of Madhya Pradesh in 1982. Shurbhi has average yield 1000 kg/ha and oil content 44.00%, and recommended for the state of Himachal Pradesh in 1995. Baner (KL-224) has average yield of 511 kg/ha and oil content 39.70%, and recommended for the states of Haryana, Punjab, Himanchal Pradesh, and Jammu & Kashmir in 2005. Himani (KL-214) variety with an average yield of 583 kg/ha and oil content 36.40 %, has been released in 2008for the states of Haryana, Punjab, Himanchal Pradesh and Jammu & Kashmir. Bhagsu (KL-215) with an average yield of 428 kg/ha and oil content 36.38 %, was released in 2010 for the states of Haryana, Punjab, Himanchal Pradesh, Uttaranchal and Jammu & Kashmir. Variety RLC-138 with h yield potential of 511 kg/ha and oil content 36.40 %, has been recommended for the states of Chhattisgarh and Odisha in 2015.Utera Alsi (RLC-143) has an average yield of 570 kg/ha and oil content of 34.01%, and has been recommended for the states of Chhattisgarh, Madhya Pradesh, Bihar, Jharkhand and Assam in 2018. Hence, our aim was to develop linseed variety for utera condition with high seed yield, high oil content and resistance/ tolerance to diseases and insect pests.

*Corresponding author Email: nrambalak@yahoo.co.in

MATERIALS AND METHODS

Local germplasm of linseed (Linum usitatissimum L.) was collected from the farmer field of Kisanganj district of Bihar during 2007. Four cycles of selection were made based on seed yield, ancillary characters and resistance/tolerance to diseases & insect pest during 2007-2008 to 2010-2011 using the pure line selection method to derive the superior pure lines. Nine promising lines were selected from local germplasm and evaluated along with two checks viz. T 397 (National check) and R552 (Zonal check) in randomized complete block design under station trials in utera condition during 2011-2012 and 2012-2013. A line performing better over both the checks and other entries was identified and designated as BAUP-101. The BAUP-101 was nominated for ICAR-AICRP trial for utera condition in 2013. The genotype BAUP-101 was tested in Initial Varietal Trial (Utera) during 2013-14 under assured moisture conditions at three (Palampur, Kangra and Malan) locations and under moisture stress conditions at six (Kanke, Raipur, Waraseoni, Keonjhar, Patna and Shillongani) locations (Anonymous, 2014). In the Advanced Varietal Trial (Utera)-1, it was tested under moisture stress condition over six (Kanke, Raipur, Waraseoni, Keonjhar,Sabour and Shillongani) locations during 2014-15 (Anonymous, 2015). Finally, the genotype BAUP101 was tested in the Advanced Varietal Trial (Utera)-2 under moisture stress condition over six (Faizabad, Raipur, Waraseoni, Keonjhar, Patna and Shillongani) locations during 2015-16 (Anonymous, 2016).The flow chart of breeding procedure is given in Fig 1.



The seed rate standardization for the new variety, BAUP 101 under utera condition was conducted at Keonjhar, Odisha during Rabi 2015-16 under AICRP Trial. Oil and fatty acid analysis was done at ICAR-Project Coordinating Unit (Linseed), Chandra Shekhar Azad University of Agriculture &Technology campus Kanpur (UP).

Molecular Characterization: DNA profiling was done for the linseed variety Sabour Tisi-1(BAUP-101) along with the reference varieties, namely, T 397, R-552 and RLC-143. DNA from all the four genotypes was extracted with the CTAB method (Doyle and Doyle 1990). Molecular analysis was done with 38 linseed specific SSR primers (Deng et al. 2010). PCR reaction conditions, and PCR profile, list of primers are presented in tables 1, 2 and 3. The PCR products were run on 3% agarose gel.

In India, linseed growing region is divided in to four zones viz; zone I (Himachal Pradesh, Haryana, Punjab and Jammu & Kashmir), zone II (Uttar Pradesh excluding Bundelkhand, Bihar, Jharkhand, West Bengal and Assam), zone III (Bundelkhand of U.P., Madhya Pradesh, Rajsthan) and zone IV (Maharastra, Chhatisgarh, Orissa, Karnataka and Andhra Pradesh). The data of Sabour Tisi-1(BAUP 101) along with T 397(National check), R552 (Zonal check) and RLC 143(Qualifying variety) was compiled for seed yield, oil content, oil yield , diseases, insect pest (Budfly) and ancillary characters from the locations of zone II (Kanke, Sabour, Faizabad and Shillongani) for submission of proposal for identification, release and notification.

Table 1 PCR reaction mix

Components for 20 µl	Volume
Sterile milliq water	13.67 µl
10X PCR buffer	2 µl
dNTPs (2.5 mM each)	1 µl
Forward primer	0.5 (10 p mol)
Reverse primer	0.5 (10 p mol)
25 mM MgCl2	-
Taq DNA polymerase (3U/µl)	0.33 µl
DNA (100 ng/µl)	2 µl

Table 2 PCR reaction profile

Steps	Time
Initial denaturation at 94°C	5 min
Denaturation at 94°C	45 sec
Annealing at **°C	45 sec
Extension at 72°C	60 sec
No. of cycles	36
Final extension at 72°C	10 min

** Annealing temperature varied between 58°C and 64°C

Table 3 SSR primers specific to the linseed variety Sabour Tisi-1

Primer	Annealing temp (0C)	Sequence	Amplicon size (bp)
LU 1	58	F:TCCCYTTATTCCCCTTTGCT R:CCAAACGCCATTGGAKAAAG	190
LU 7	60	F: CATCCAACAAAGGGTGGTG R: GGAACAAAGGGTAGCCATGA	150
LU 9	60	F:CCTCGCTCTTTTCTTCTCTC R:GGGGAGCTATTAGGACTTCT	185
LU 11	61	F:CTCTCCCTCGCTCTTTTCTT R:GGGGGAGCTATTAGGACTTCT	170
LU 15	60	F: TGGACGACGATGAAGATGAA R: CCGCCGGGTACACTACTACT	130
LU 21	60	F: AAGGGTGGTGGTGGGAAC R: GTTGGGGTGAAGAGGAACAA	180
LU 24	60	F:GTGTGGGAATTGGACACTTG R:CAAACCGAAGAGGCAAGAAG	170

RESULTS AND DISCUSSION

There was sufficient amount of variability for characters, number of capsules per plant, seed size, plant height, number of primary branches per plant, bud fly infestation and disease reactions in the germplasm collected from farmer's field of Kisangani district of Bihar. The presence of variability within the germplasms and its adaptability provided opportunity for improvement using the pure line selection method. The details of the breeding procedure employed are represented in Fig1. A line showing superior performance under station trials was identified. The promising line BAUP-101 was nominated in Initial Varietal Trial (Utera) of All India Coordinated Varietal Trial in 2013.

The seed yield data of trials under moisture stress conditions of All India Co-ordinated Varietal Trials of zone II (Anonymous, 2014, 2015 & 2016) (Table 4) revealed that the weighted mean of Sabour Tisi-1 (BAUP-101) was 686 kg/ha, which showed 27.75%, 142.40% and 3.00% yield superiority over the checks T 397, R552, and RLC 143, respectively. Further, the frequency of Sabour Tisi-1 was 4/7 in the top three groups pooled for three years. These results showed the potentiality of Sabour Tisi-1 over checks and qualifying variety.

The weighted mean of oil per cent of Sabour Tisi-1 was 33.24 %, showed at par with check varieties (T397 & R 552) and qualifying variety (RLC 143) but its weighted mean oil yield was 196 kg/ha, which was 20.25 %, 80.46% and 3.70% higher than the T 397, R 552 and RLC 143, respectively (Table 5). Sabour Tisi-1 had 5.41% palmitic acid, 5.83% stearic acid, 35.6% oleic acid, 18.17% linoleic acid, 35.00% linolenic acid, and 153.88% iodine value (Table 6). Strikingly, Sabour Tisi-1 has higher levels of oleic acid and concomitantly reduced levels of linolenic acid.

The results of different seed rates on yield of the genotypes (Table 7) indicated that the highest yield of Sabour Tisi-1 was at 40 kg per ha seed rate. The yield penalty at seed rates of 30 kg per ha and 50 kg/ha were 32.55% and 24.71%, respectively in comparison to seed rate of 40 kg /ha for Sabour Tisi-1. Hence, the seed rate of 40 kg/ha was found to be optimum seed rate under utera condition for higher productivity.

The severity of diseases was recorded for wilt, rust; Alternaria blight and powdery mildew under artificial condition and bud fly infestation under natural condition have been presented in Table 8. Results showed that disease reactions of Sabour Tisi-1 were comparatively lower than the T 397 and R552 but it was moderately susceptible for wilt, rust, Alternaria blight and powdery mildew. Sabour Tisi-1 had lower budfly infestation and was similar in comparison to T 397 and RLC 143. Hence, it requires necessary plant protection measures for cultivation.

The average days to maturity, number of capsule per plant, number of seeds per capsule and 1000- seed weight for Sabour Tisi-1 were 126 days, 26,7.7 and 5.0 gram, respectively. The Sabour Tisi-1 has semi- erect growth plant habit; small, blue colour and funnel shaped flower; twisted petal aestivation; faint blue colour filament, violet colour anther and colourless stigma ; and medium capsule size, light brown colour seed and small size seed. The photograph of single plant and seeds (Fig 2) indicates the morphological traits at glance.

Molecular analysis: A total of 38 primers were used to compare the Sabour tisi-1 with three reference varieties, namely, T397, R552 and RLC143. All of them fetched distinguishable amplification products, of which 12 primers showed polymorphism among the four genotypes. Among these, 7 primers (LU 1, LU7, LU9, LU11, LU15, LU21, and LU24) produced amplicons specific to the variety Sabour Tisi-1(BAUP-101) (Fig.3). Thus, molecular data revealed that Sabour tisi-1 could be differentiated from other reference varieties.

The proposal of variety Sabour Tisi-1 (BAUP 101) was submitted to Varietal Identification Committee of ICAR during Annual Group Meeting on linseed at VNMKV, Parbhani (MS) on 03.09. 2016. The Varietal Identification Committee identified Sabour Tisi-1 (BAUP 101) for high yield for utera condition of zone II comprising the state of Bihar, Jharkhand, West Bengal, Assam and UP excluding Bundelkhand. This variety has national identity number IC 620661 which was given by Division of Germplasm Conservation, ICAR-National Bureau of Plant Genetic Resources, Pusa Campus New Delhi, vide Letter No. GCD/RV/October/2016 dated 14.10.2016. Further this variety has been recommended for Release and Notification (Central Varieties) by Central Sub-Committee on Crop Standards, Notification and release of Varieties for Agricultural Crops, Government of India, Ministry of Agriculture and Farmers Welfare (Department of Agriculture Cooperation and Farmers Welfare) vide notification No.3-6212017-SD.lV dated: 8th March, 2018. Finally this was published in the Gazette of India: Extraordinary [Part II-Sec. 3(ii)] bearing S.O. 1379 (E) dated 27.03.2018.

Table 4 Mean seed yield performance linseed genotype s in utera trials under AICRP linseed trials of zone II

Item	Year of testing	Locations	Sabour Tisi-1	T 397	R 552	RLC 143
Mean yield (Kg/ha)	2013-14	3	554	341	253	768
	2014 -15	2	789	669	283	614
	2015-16	3	749	646	314	599
Weighted Mean		-	686	537	283	666
Percentage increase over the checks & qualifying varieties		-	-	27.75	142.40	3.00
Frequency in the top three groups (pooled for 3 yrs.)		-	4/7	2/7	1/7	5/7

Table 5 Mean oil content and oil yield performance linseed genotype s in utera trials under AICRP linseed trials of zone II

Item	Year	Locations	Sabour Tisi-1	T 397	R 552	RLC 143
Oil content (%)	2013-14	3	32.68	35.57	34.13	33.9
	2014 -15	6	35.23	34.42	34.98	34.49
	2015 -16	5	31.19	33.60	31.69	33.09
	Weighted mean	14	33.24	34.37	33.62	33.86
% increase or decrease over the checks & qualifying varieties				(-) 0.03	(-)0.01	(-)0.02
Oil yield (kg/ha)	2013-14	3	148	102	91	190
	2014 -15	2	212	174	129	175
	2015 -16	3	234	217	100	198
	Weighted mean	8	196	163	104	189
% increase or decrease over the checks & qualifying varieties				20.25	80.46	3.70

Table 6 Mean fatty acids content and iodine value performance linseed genotype s in utera trials under AICRP linseed trials of zone II

Variety	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Iodine value
Sabour Tisi-1	5.41	5.83	35.6	18.17	35.00	153.88
T 397	7.52	3.84	19.31	13.96	55.37	185.93
R552	10.26	2.50	22.04	15.76	49.43	175.84
RLC 143	4.72	2.51	28.58	18.32	46.32	177.76

Table 7 Mean seed yield performance under different seed rates of linseed genotypes in utera trial under AICRP linseed trial at Keonjhar (Odisha)

Item	Seed rate(kg/ha)	Sabour Tisi-1	T-397	RLC-143
Yield (Kg/ha) under different seed rates	30	464	449	421
	40	688	680	642
	50	518	590	574
Yield (Kg/ha) under recommended dose	40	688	680	642
Percentage gain or loss under other doses	30	(-) 32.55		
	50	(-) 24.71		

Table 8 Major disease reactions under artificial condition (2014-15 and 2015-16) and Budfly infestation under natural condition (2013-16 to 2015-16) of linseed genotype s under AICRP linseed trials of zone II

Disease/insect pest	Sabour Tisi-1	T 397	R 552	RLC 143
Wilt	MS	S	MS	MS
Rust	MS	HS	HS	R
Alternaria blight	MS	S	S	MR
Powdery Mildew	MS	S	S	MS
Budfly infestation	MR	MR	MS	MR

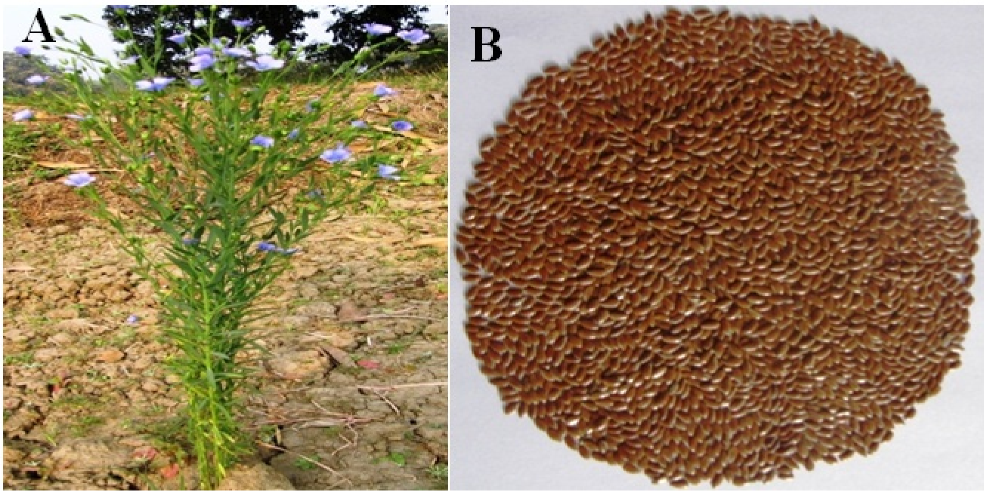


Fig. 2: Single plant of Sabour Tisi-1 (A) and seeds (B).

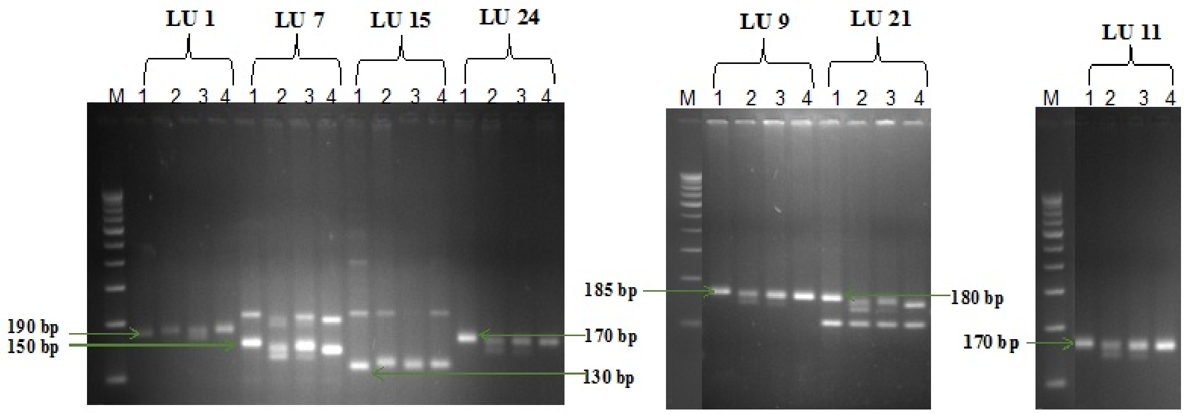


Fig. 3. SSR primers specific for the linseed variety Sabour Tisi-1 (BAUP-101). (M: Marker 100 bp, Lane 1: Sabour Tisi-1 (BAUP-101), Lane 2: T-397, Lane 3: R-552, Lane 4: RLC-143)

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Effect of biochar on soil physical and hydrological properties, and on growth, yield, quality of *rabi* groundnut (*Arachis hypogaea* L.) in red sandy loam soils of North Coastal Andhra Pradesh

B GOWTHAMI AND P GURUMURTHY

Agriculture College, Acharya NG Ranga Agricultural University, Naira-532 185, Andhra Pradesh

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ABSTRACT

A field experiment was conducted in red sandy loam soils of North Coastal Andhra Pradesh to study the effect of biochar on soil physical and hydrological properties, and on growth and yield of rabi groundnut (variety K-6) during 2018-19. Biochar application to soil had significant influence on soil bulk density, porosity and maximum water holding capacity, non-significant influence on final infiltration rate and saturated hydraulic conductivity. Significantly low bulk densities (1.40 mg/m3 and 1.39 mg/m3) and high total porosities (47.17% and 47.55%) of soil at sowing stage were recorded in treatments which received biochar @ 6 t //ha (T5 & T8) and these treatments were on par with treatments which received biochar @ 4 t /ha(T4 and T7) and @ 2 t //ha (T3 and T6). However, T5 and T8 were significantly lower in bulk densities and higher in total porosities when compared to T1 (control) and T2 (100% RDF). Highest bulk density of 1.58 Mg /m3 and lowest total porosity of soil (40.38%) was noticed in T1 (control). Soil penetration resistance and soil temperature followed the trend of bulk density. In general, soil bulk density, soil penetration resistance and soil temperature increased from sowing to harvesting stage of groundnut crop, but the percent pore space decreased. Biochar addition to soil impacted the maximum water holding capacity (MWHC) by recording increased water retention with increased rate of biochar addition from control to 2 t /ha up to 6 t /ha. Biochar addition @ 6 t /ha (T5 & T8) significantly increased MWHC of soil when compared to control (T1) and 100% RDF (T2). A slight but non-significant decrease in final infiltration rate and saturated hydraulic conductivity was noticed by biochar addition. Groundnut crop growth in the form of leaf area index at pod development stage was highest (3.16) in T5 (biochar 6 t /ha + 100% RDF) which was on par with T4 (biochar 4 t /ha + 100% RDF) and both T5 & T4 were significantly higher than T6, T7, T8, T2 and T1. In general, the dry matter accumulation increased from peg penetration to harvest. Highest dry matter accumulation of 2950.90 kg /ha and 6427.54 kg /ha, respectively at peg penetration and pod development stage was observed in T5 (100% RDF + biochar @ 6 t /ha) which was on par with T4 (100% RDF + biochar @ 4 t /ha), T3 (100% RDF + biochar @ 2 t /ha), T8 (75% RDF + biochar @ 6 t /ha) treatments. Groundnut pod yield was highest (4020 kg /ha) in T5 treatment (100% RDF + biochar @ 6 t /ha), which was on par with T4 (100% RDF + biochar @ 4 t /ha) and T8 (75% RDF + biochar @ 6 t /ha). From these observations, it could be concluded that application of biochar at either @ 4 t/ha + 100 % RDF or @ 6 t /ha + 75% RDF, resulted in better soil physical environment and also increased availability of nutrients which resulted in higher plant growth, dry matter production and pod yield in groundnut.

Keywords: Biochar, Groundnut, Soil hydrological properties, Soil physical properties

Biochar is a fine grained, carbon rich, porous product obtained when biomass is subjected to thermo chemical conversion process [pyrolysis] at temperature of 300-350?C in an environment with little or no oxygen. It is not a pure carbon, but mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions. Biochar can be prepared by several methods like pit method, drum method, heap method etc. According to Ministry of New and Renewable Energy (MNRE, 2009), Government of India, about 502 million tonnes of crop residue is generated annually in the country and had surplus waste of 141 million tonnes per annum, of which about 93 million tonnes of crop residues are burnt in each year (IARI, 2012). In Andhra Pradesh 43.89 million tonnes of crop residue is generated annually and surplus waste of 7.0 million tonnes per annum, of which 2.73 million tonnes is burnt each year (IARI, 2012). Traditional burning of crop residue provides a fast way to clear the agricultural crop residue but it leads to loss of nutrients (N and S), organic matter, and microbial activity and also leads to environmental pollution. Hence, conversion of organic waste to produce biochar using the pyrolysis process is one viable option that can enhance natural rates of carbon sequestration in the soil, safe recycling of farm waste and improving the soil quality.

Several studies have been carried out throughout the world to identify the effects of incorporating organic matter into the soil, and the resulting advantages for its physical and hydrological properties are well known (Castellini et al., 2014; Vivek Sharma, 2018). In recent years there has been increased use of biochar as an amendment to agricultural soils, since it is improving both crop productivity and soil quality (Vaccari et al., 2011; Baronti et al., 2014). Biochar may be potentially integrated into sustainable agricultural systems. Most of the available studies focus on the biochemical effects of biochar on amended soil, including the nutrients that it makes available, as well as on its impact on CEC, pH, vegetative growth, crop yield, and its C sequestration potential (Atkinson et al., 2010; Mukherjee and Rattan Lal, 2013). However, its incorporation into the soil may modify the physical and hydraulic properties of the porous medium, such as bulk density, water retention, hydraulic conductivity, porosity and penetration resistance. This is mainly due to both its highly porous structure and the exposed surface area (Lehmann and Joseph, 2009). However, to date, little attention has been given to the accurate evaluation of the effects of biochar on physical and hydrological properties of the soil.

Liu et al. (2013) reported that field application of biochar @ 10 t /ha increases crop productivity with greater increase for legumes (30%) than cereal crops (10%). Yamato et al. (2006) reported a significantly increased peanut yield following biochar amendment of an infertile soil in Sumatra with no significant change in yield for fertile soil, along with general increase in soil pH, available N, P and CEC. Hence, the present study was carried out to evaluate the impact of biochar additions on the physical and hydraulic properties of sandy loam soil in relation to growth and pod yield of rabi groundnut.

MATERIALS AND METHODS

The present study was carried out during rabi, 2018-19. The experimental plot was geographically situated at an altitude of 12 m above mean sea level830 56'.602" E longitude and 180 22' 752" N latitude in the Agricultural College Farm, North Coastal Andhra Pradesh. The Experimental soil texture was sandy loam, soil pH 6.13, EC 0.27 dS m-1 at 25 0C, organic carbon of 0.36 %, CEC 14.62 cmol (p+) //kg. Soil available nitrogen 130.50 kg //ha, available P2O5 15.67 kg //ha, and available K2O 195.4 kg //ha respectively. Exchangeable Calcium 6.10 cmol (p+) /kg and Magnesium 1.72 cmol (p+) /kg and available Sulphur 17.20 (mg /kg). Biochar was prepared under the low oxygen conditions by pyrolysis process with dried mesta sticks with 29.4 per cent recovery. The biochar was alkaline in reaction (pH 8.38), slightly saline (EC 2.39) with organic carbon 35.04%, CEC 54.26 cmol (p+) /kg soil. The field experiment was laid in RBD with eight treatments using groundnut (Variety - Kadiri 6) as a test crop. The treatment includes: T1 - Control (No fertilizer and biochar, only general management); T2 - RDF only (30-40-50, N, P2O5 and K2O /ha, respectively); T3- Biochar @ 2 t /ha + RDF; T4- Biochar @ 4 t /ha + RDF; T5 - Biochar @ 6 t /ha + RDF; T6 - Biochar @ 2 t /ha +75% RDF; T7- Biochar @ 4 t /ha +75% RDF; T8- Biochar @ 6t /ha +75% RDF.

The physical and hydrological properties were determined at sowing, peg penetration and harvest stages of groundnut crop. Soil bulk density was determined by using core sampler method (Black, 1965). Soil porosity was calculated using bulk density and particle density in the following formula and the results expressed as percentage.

$$\text{Porosity (\%)} = 1 - \frac{BD}{PD} \times 100$$

Where, BD = Bulk density (Mg /m3)
PD = Particle density (Mg /m3)

Penetration resistance of the soil was measured by a cone penetrometer (Davidson, 1965) at regular intervals during the crop growth period. Soil temperature was recorded at different stages of crop growth period by employing soil thermometer at 5 cm depth and was determined one day before giving irrigation between 9:30 AM to 10:30 AM and expressed as 0C. Maximum water holding capacity was determined by Keen Raczkowski brass cup as described by Sankaram (1966). Final infiltration rate was determined using double ring infiltrometer following variable head method as suggested by Bertrand (1965) and the results were expressed in mm /hr. Undisturbed soil samples collected in cylindrical core sampler from 0-15 cm soil depth were used for the determination of saturated hydraulic conductivity in the laboratory by constant head method as per the procedure outlined by Jalota et al. (1998).

Plant height (cm) was measured from the base of the plant to the top of the main shoot of the five labeled plants in each plot. Leaf area was measured by using leaf area meter and was expressed as leaf area index (LAI) using the formula suggested by Watson (1952). Plant samples for dry matter study were collected at peg penetration, pod development and harvest stages. At each sampling, five plants were uprooted at random in each treatment in the sampling row. These samples were shade dried followed by oven drying at 65oC till a constant weight was recorded. The dry weight of these samples was recorded. Later, dry matter production was computed on hectare basis and expressed in kg/ha. Pods from the net plot area were sun dried, cleaned and pod weight was recorded on the basis of dry pod yield (in kg) per plot. Based on the yield per hectare was computed and expressed in kg /ha.

RESULTS AND DISCUSSION

Soil Physical Properties

Bulk density (BD): Addition of biochar to soil had impact on soil bulk density (table 1). Significantly low bulk densities (1.40 Mg/m3 and 1.39 Mg/m3) of soil at sowing stage were recorded in treatments which received biochar @ 6 t /ha (T5 & T8) and these treatments were, although slightly lower in bulk density but on par with treatments which received biochar @ 4 t /ha(T4 and T7) and @ 2 t /ha (T3 and T6). However, T5 and T8 were significantly lower in bulk densities when compared to T1 (control) and T2 (RDF only). Highest bulk density of 1.58 Mg/m3 was noticed in T1 (control). In general, soil bulk density increased from sowing to harvest stage of groundnut. A dilution effect caused by the addition of light weight, low density material like biochar to a soil might partly result in decrease in soil bulk density (Lu et al., 2015). Esmaeelnejad et al. (2016) reported the decrease in soil bulk density of soil with the incorporation of biochar.

Soil porosity: Increasing trend in soil porosity with increased rates of application of biochar compared to control treatment was observed (Table 1). The soil porosity at sowing in biochar applied treatments viz., T8 (47.55 %), T5 (47.17 %), T7 (47.17 %), T4 (46.79 %) and T6 (46.04 %) were on par and significantly superior to biochar not applied treatments (T1 and T2). Lowest porosity of 40.38 per cent was associated with T1 (control). The increase in porosity due to biochar addition might be because of reduction in soil bulk density and also dilution effect of biochar in soil. The reports of Herath et al. (2013) were also in tune with these results regarding increased overall volume of pores by addition of biochar to soil. Porous nature of biochar was also a reason for the increase in soil porosity (Mukherjee et al., 2011). The soil porosity decreased towards harvest stage in all treatments due to consolidation of soil by irrigations given to field.

Penetration resistance of soil: Biochar addition @ 6 t/ha (T5 and T8) significantly decreased soil penetration resistance compared to control (T1) and RDF alone (T2) treatments (Table 1). At peg penetration stage of groundnut, lowest penetration resistance of 35.40 and 35.73 kg/cm2 was observed when biochar was added @ 6 t/ha (T5 and T8, respectively), which was on par with 4 t/ha biochar added treatments (T4 and T7) and significantly lower than biochar not added treatments (T1 and T2). The decreased penetration resistance of soil is mainly due to highly porous structure of biochar (Lehmann and Joseph, 2009). In general soil penetration resistance increased from sowing to harvest stage of groundnut crop.

Soil temperature: Soil temperature (5cm depth) was influenced by biochar addition (Table 1). Significantly low soil temperatures of 19.25 0C and 19.83 0C were recorded at sowing when biochar added @ 6 t/ha (T5 and T8) and these treatments were, on par with treatments which received biochar @ 4 t/ha (T4 and T7) and @ 2 t/ha (T3 and T6). T5 and T8 were significantly lower in soil temperature when compared to T1 (control) and T2 (100% RDF only).

Soil Hydrological Properties

Maximum water holding capacity (MWHC): Increased rates of addition of biochar to soil (2 t/ha to 6 t /ha) increased the maximum water holding capacity (MWHC) of soil (Table 2). At sowing high MWHC of 47.23, 46.73 per cent was observed in T8 (75% RDF + biochar @ 6 t /ha) and T5 (RDF + biochar @ 6 t/ha), respectively and both the treatments were statistically at par and significantly superior to T1 (39.31%) and T2 (41.44%). However T3, T4, T6 and T7 treatments although recorded slightly higher MWHC than T1 and T2 they were not significant. An increase in maximum water holding capacity was noticed with increased rates of biochar application (2 t/ha, 4 t/ha and 6 t/ha) which were on par. Addition of porous biochar with high specific surface area to the soil increased porosity and water holding capacity of soils. Increase in MWHC of soil with biochar addition was observed by Verheijen et al. (2010) as biochar addition increases specific surface of soil. Herath et al. (2013) also noticed increase in MWHC of coarse textured soils with addition of biochar which could be due to increase in soil micro porosity and high absorptive nature of biochar to water.

Final infiltration rate: Biochar addition to soil did not significantly influence soil infiltration rate (Table 2). A slight but non-significant decrease in infiltration rate was noticed with increasing rate of biochar application (2 t/ha to 6 t/ha). Highest infiltration rate of 18.80 mm/hr was observed with T1 (control) and lowest infiltration rate of 16.33 mm/hr was noticed in T8 (75 % RDF + biochar @ 6 t /ha) at sowing. The final infiltration rate of soil was in general decreased from sowing to harvest due to consolidation of soil by irrigations given to field. Herath et al. (2013) also reported slight decrease in water percolation by biochar application to coarse textured soil which was attributed to increase in soil micro pores as well as adsorptive surface in soil.

Saturated hydraulic conductivity: Addition of biochar to soil did not significantly influence the saturated hydraulic conductivity (Table 2). A slight decrease in hydraulic conductivity was noticed with increased rates of biochar application. At sowing highest hydraulic conductivity of 2.49 cm/h was observed in T1 (control) and lowest of 2.03 cm/h was noticed in T5 (RDF + biochar @ 6 t/ha). Further, hydraulic conductivity showed decreasing trend towards harvest stage. Ouyang et al. (2013) reported no impact by addition of biochar in loamy soils on saturated hydraulic conductivity.

Plant growth and yield parameters: Biochar application to soil caused slight increase in plant height but was not significant (Table 3). Leaf area index increased from peg penetration to pod development. At pod development stage, highest LAI (3.16) was recorded in T5 treatment (RDF + biochar @ 6 t /ha) which was significantly higher than T1 (control), T2 (RDF) and T6 (75% RDF + biochar @ 2 t/ha). In general, the dry matter accumulation increased from peg penetration to harvest. Highest dry matter accumulation of 2950.9 kg /ha and 6427.5 kg/ha, respectively at peg penetration and pod development stage was observed in T5 (RDF + biochar @6 t /ha) which was on par with T3 (RDF + biochar @ 2 t /ha), T4 (RDF + biochar @ 4 t /ha), T8 (75% RDF + biochar @ 6 t/ha) treatments. However, T5 was significantly superior to treatments T6 (75% RDF + biochar @ 2 t/ha), T7 (75% RDF + biochar @ 4 t/ha), T2 (RDF) and T1 (control). Application of biochar resulted in better soil physical environment and also increased availability of nutrients by improving biological activity which resulted in higher plant growth and biomass production (Laxman Rao et al., 2017). Lehmann et al. (2003) opined that biochar addition improves the availability of nutrients thus promote vegetative growth and increases dry matter production.

Haulm and pod yield: Haulm yield of groundnut (Table 3) was highest (5131 kg /ha) in T5 (RDF + biochar @ 6 t/ha) which was on par with T4 (4943 kg/ha), T3 (4829 kg/ha), T2 (4565 kg/ha) and T8 (4775 kg/ha) treatments. However, the haulm yield in T5 was significantly higher than that of T1 (control), T6 (75% RDF + biochar @ 2 t/ha) and T7 (75% RDF + biochar @ 4 t/ha). Lowest haulm yield of 3646 kg/ha was observed in T1 (control). Effect of biochar on groundnut pod yield revealed that highest pod yield (4012 kg/ha) was recorded in T5 (100% RDF + biochar @ 6 t/ha) which was on par with T4 (3887 kg/ha), T8 (3782 kg/ha), T7 (3613 kg/ha). However, the pod yield of groundnut in T5 was significantly higher than that of T1 (control), T2 (RDF), T3 (RDF + biochar @ 2 t/ha) and T6 (75% RDF + biochar @ 2 t/ha). The increase in pod yield with the biochar addition was perhaps due to the increased retention of water and nutrients in soil, availability of soil bounded nutrients through chelation with concomitant absorption by the plants as concluded by Agegnehu et al. (2015).

Favourable improvement of soil physical and hydrological properties viz., bulk density, porosity, soil temperature, penetration resistance and maximum water holding capacity were noticed with addition of biochar to soil compared to biochar not applied treatments in sandy loam soils. Application of biochar significantly increased growth, and dry matter production of groundnut crop. Higher pod yields of groundnut was recorded when biochar was applied @ 6 t/ha + RDF, 4 t/ha + RDF and 6 t/ha + 75% RDF which were significantly higher compared to 'control' and 'RDF alone' treatments. At pod development stage, highest LAI (3.16) was recorded in T5 treatment (RDF + biochar @ 6 t/ha) which was significantly higher than T1 (control), T2 (RDF alone) and T6 (75% RDF + biochar @ 2 t/ha). Highest dry matter accumulation was observed in T5 (RDF + biochar @6 t/ha) which was on par with T3 (RDF + biochar @ 2 t/ha), T4 (RDF + biochar @ 4 t/ha), T8 (75% RDF + biochar @ 6 t/ha) treatments. Application of biochar resulted in better soil physical environment and also increased availability of nutrients which resulted in higher plant growth, dry matter production and pod yield in groundnut.

Table 1 Effect of biochar on soil physical properties

Treatments	Bulk density (Mg/m3)			Porosity (%)			Penetration resistance (kg/cm2)			Soil temperature (0C) (at 5 cm soil depth)		
	Sowing	Peg penetration	Harvest	Sowing	Peg penetration	Harvest	Sowing	Peg penetration	Harvest	Sowing	Peg penetration	Harvest
T1	1.58	1.59	1.62	40.38	40.00	38.87	44.13	42.97	42.53	23.50	25.70	28.27
T2	1.56	1.55	1.60	41.13	41.51	39.62	43.53	41.37	39.37	22.93	25.50	27.67
T3	1.45	1.48	1.52	45.28	44.15	42.64	40.60	39.57	37.47	21.47	23.50	26.63
T4	1.41	1.42	1.45	46.79	46.42	45.28	38.40	36.60	33.53	20.77	23.40	26.40
T5	1.40	1.41	1.43	47.17	46.79	46.04	35.40	33.17	30.57	19.83	22.57	25.57
T6	1.43	1.48	1.53	46.04	44.15	42.26	40.27	39.57	38.40	21.53	23.40	27.30
T7	1.40	1.43	1.44	47.17	46.04	45.66	37.47	35.63	34.63	21.47	22.70	26.60
T8	1.39	1.42	1.43	47.55	46.42	46.05	35.73	33.60	31.33	19.25	22.33	25.43
SEm (±)	0.04	0.04	0.04	1.80	1.69	1.74	1.95	2.14	2.48	1.05	1.16	1.31
CD (p=0.05)	0.13	0.12	0.13	5.46	5.14	5.29	5.93	6.50	7.54	3.17	3.33	NS
CV (%)	5.75	5.32	5.36	6.83	6.54	6.92	8.60	9.82	11.98	8.50	8.62	8.49

Table 2 Effect of biochar on soil hydrological properties

Treatments	MWHC (%)			Final infiltration rate (mm/hr)			Saturated hydraulic conductivity (cm/hr)		
	Sowing	Peg penetration	Harvest	Sowing	Peg penetration	Harvest	Sowing	Peg penetration	Harvest
T1	39.31	39.08	38.17	18.80	17.28	15.20	2.49	2.43	2.25
T2	41.44	40.57	39.17	18.57	17.33	15.57	2.45	2.40	2.21
T3	44.53	43.62	41.95	17.33	16.19	15.20	2.38	2.31	2.17
T4	45.89	44.02	43.28	17.10	16.33	14.37	2.16	2.12	2.10
T5	46.73	45.36	44.73	16.67	15.67	14.57	2.03	1.94	1.91
T6	44.00	42.37	41.37	17.77	16.77	14.21	2.32	2.30	2.13
T7	44.86	43.75	43.08	16.67	16.33	14.57	2.16	2.07	1.92
T8	47.23	46.12	46.25	16.33	15.44	13.86	2.10	2.08	1.96
SEm (±)	1.58	1.56	1.66	1.03	1.08	0.88	1.23	1.01	0.91
CD (p=0.05)	4.84	4.78	4.99	NS	NS	NS	NS	NS	NS
CV (%)	6.14	6.24	6.76	8.77	9.71	9.43	11.73	10.17	9.62

Table 3 Effect of biochar on growth parameters, dry matter production, haulm and pod yield of groundnut

Treatments	Plant height (cm)			Leaf area index			Dry matter production (kg/ha)		Haulm yield (kg /ha)	Pod yield (kg/ha)
	Peg penetration	Pod development	Harvest	Peg penetration	Pod development	Harvest	Peg penetration	Pod development		
T1	31.57	43.17	44.00	1.62	2.30	2.33	2134.7	4972.7	3646	2876
T2	34.17	44.00	47.17	1.85	2.68	2.45	2544.6	5643.3	4565	3436
T3	34.17	45.17	48.00	2.01	2.85	2.61	2669.1	5857.9	4829	3538
T4	35.00	46.33	49.18	2.05	2.93	2.69	2834.9	6213.7	4943	3887
T5	35.67	47.17	50.13	2.19	3.16	2.73	2950.9	6427.5	5131	4020
T6	31.00	44.00	45.00	1.83	2.57	2.40	2507.4	5473.0	4357	3392
T7	32.00	44.33	45.67	1.96	2.75	2.42	2732.1	5610.6	4408	3613
T8	33.33	45.00	45.83	2.08	2.83	2.58	2784.3	5705.8	4775	3782
SEm (±)	2.12	2.59	2.66	0.07	0.09	0.07	117.2	244.1	215.1	157.0
CD (p=0.05)	NS	NS	NS	0.21	0.26	0.23	355.5	640.5	652	476
CV (%)	11.10	9.89	9.20	6.51	6.63	5.32	7.67	7.36	8.13	7.60

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Influence of fly ash based seed pelleting on root rhizosphere populations of sesame

M PRAKASH*, G SATHIYA NARAYANAN AND B SUNIL KUMAR

Annamalai University, Annamalai Nagar - 608 002, Tamilnadu

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ABSTRACT

Sesame (Sesamum indicum L.) is one of the most ancient oilseed crops. This important annual oil seed crop has been cultivated widely for its edible oil (42-54%) and protein (22-25%). Sesame oil has two important components, sesamin and sesaminol, which play a major role in antioxidant activity. Seed pelleting is an effective, simple technique to enhance crop establishment under unfavourable environmental conditions, particularly in the case of small seeded crops like sesame. The role of rhizosphere population is important in the context of providing conducive environment and enhancing the yield of the growing plants. Fly ash is a coal combustion residue of thermal power plants. It has great potentiality in agriculture due to its efficacy in modification of soil health and crop performance. The high concentration of elements (K, Na, Zn, Ca, Mg and Fe) present in flyash increases the yield of many agricultural crops. The role of flyash in influencing microbial activity through increased microbial population was studied in sesame through seed pelleting technique. Field experiments were conducted with flyash @ 200, 250 and 300 g with rice gruel and gum arabic (as adhesives) to study its influence on crop growth, soil parameters and microbial population in sesame. The experimental results revealed that seed pelleting with fly ash increased crop growth, soil parameters and microbial populations of bacteria, fungi, Actinomyctes, rhizobium, Azospirillum and seed yield in sesame, when compared to other treatments.

Keywords: Flyash, Rhizosphere population, Seed pelleting

Sesame, a plant of Pedaliaceae family is an annual, tropical, herbaceous and predominantly self-pollinating plant. India is one of the major producers of oilseeds and the Indians consume substantial quantity of edible oil primarily for cooking. Sesamum indicum L. is one of the world's important oil crops. It was one of the first oil seeds from which oil was extracted by the ancient Hindus, which was used for certain ritual purposes. The whole seeds, seed oil and meal are its primary marketable products. It is called as the "queen" of oilseeds in view of its oil (50-60%), protein (18-25%), carbohydrate and ash. Sesame seeds have digestive, rejuvenative, anti ageing properties and rich in vitamin E, minerals like calcium, phosphorus, iron, copper, magnesium, zinc and potassium. This unique composition coupled with high-unsaturated fatty acid (Linolinic and Tocopherol) makes the sesame oil nearly perfect food oil (El Khier et al., 2018).

The low productivity in sesame is due to the fact that it is grown mostly in marginal and rainfed areas. In any crop, seed is the basic input in agriculture and production and supply of quality seeds to the farmers is essential to achieve the goal of self sufficiency. Under rain fed conditions and in the case of small seeded crops like sesame, seed pelleting is one of the simplest and easiest method to invigorate the seeds and enhance seedling vigour, which in turn will reflect in yield. Pelleting is one type of seed coating technology that is defined as the deposition of a layer of inert materials that may change and/or increase the original shape and size of the seed, resulting in substantial weight increase and improved plantability (Butler, 1993). In case of small seeded crops like sesame, it is the most useful method, which will increase size, shape and vigour of seedling. Seed pelleting has many advantages in crop production. It is the easier, low cost technique followed in direct sown crops which need initial vigour for sustained crop growth and development. Seed pelleting is an effective, practical technique to enhance rapid and uniform emergence, high seedling vigor, and better yields in many field crops particularly under unfavourable environmental conditions (Powell and Matthews, 1988). It provides an opportunity to provide a package of materials (nutrients, bio fertilizers etc.) which will help to influence micro environment of each seed by supplying nutrients from the earlier stages of the crop. Ryu et al. (2006) reported that seed germination and root colonization of sesame were significantly improved when the sesame seeds were pelleted with a combination of clay, vermiculite and talc; consequently the grain yield was increased by 10.2 per cent. Pelleting of the seed with suitable adhesive filler and bioactive chemical focuses on the performance of seeds with respect to achievement of desired population. Even though seed pelleting work has been reported in sesame by many workers (Tuna Dogan et al., 2005; Kalaiyarasi and Ramu, 2018; Kamaraj et al., 2017), the work on using flyash as pelleting material has been limited.

In India and many other countries, major source of electrical energy is coal based thermal power plants, which produce 175 million tonnes of fly ash which would require about 40,000 hectares of land for the construction of ash ponds (Lal et al., 2012). Flyash is generated during the combustion of coal in coal fired thermal power plants and other industries like paper industry, where coal is used as the raw material. Disposal of this huge quantity of ash is thus a

Corresponding author: geeth_ prakash@yahoo.co.in

great problem which would aggravate due to erection of more and more thermal power plants and paper industries. Indian thermal power stations consume about 150 million tonnes of coal each year generating some 30 million tonnes of highly polluting flyash at the rate of one lakh tonnes a day (Sankarapandi, 1994). The Ministry of Power and Planning Commission estimates that the coal requirement and generation of fly ash during the year 2031-32 would be around 1800 million tonnes and 600 million tonnes respectively. The fly ash utilization in the country is estimated to be about 59 per cent only (Kanungo, 2013).

This flyash which is adequately available from thermal power stations can be utilised in agriculture as seed pelleting material. Approximately, 95 to 99 per cent of fly ash consists of oxides of Si, Al, Fe & Ca and about 0.5 to 3.5 per cent consists of Na, P, K & S and remaining flyash will contain trace elements. The concentration of nearly all elements present in flyash is higher than in soil except organic carbon and nitrogen. These nutrients present in the fly ash may be helpful in enhancing seed germination, seedling vigour and establishment when applied as seed pelleting material. Even though there are some reports on flyash seed pelleting on few crops (Prakash et al., 2012; Prakash et al., 2014a; Prakash et al., 2014b; Prakash et al., 2014c), the effect of fly ash seed pelleting on Rhizosphere population is very meagre. Hence in the present study, an attempt was made to investigate the effect of flyash seed pelleting on crop growth, soil parameters and microbial population in sesame.

MATERIALS AND METHODS

The experiments were conducted at the Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar (11°24'N latitude and 79°44'E longitude with an altitude of + 5.79 m above mean sea level), Tamil Nadu, India in two seasons viz., season 1 (S1) (January - April) and Season 2 (S2) (June - Sep) during 2017-2018. Genetically pure seeds of sesame cv. TMV 3 were graded for uniformity using appropriate round perforated metal sieves and subjected to pelleting treatments with flyash collected from Neyveli Lignite Corporation, Neyveli, Tamil Nadu, India. The physiochemical properties of lignite flyash are as given below.

The experiment was carried out with the following pelleting treatments with two different types of adhesives i.e., the common adhesive, gum @ 10 per cent (100 ml per kg of seed) and rice gruel. Gum arabic, also known as gum acacia, is a natural gum made of hardened sap taken from two species of the acacia tree; Acacia senegal and Acacia seyal. Rice gruel is a type of rice porridge popular in many Asian countries. It is recognised by its thick texture and due to its properties of glue and /or binder, it is used as an adhesive material in rural areas commonly. In pelleting treatment, the seeds were mixed with the common adhesives and were sprinkled with the flyash at various doses to seed and rolled for uniformity. The thickness of the seed coating is dependent on the amount of sticker in relation to the amount of seed. The total mixing time did not exceed four minutes since prolonged agitation would damage the seeds or chips off pelleted coat.

Parameters	Values
pH (1:2.5)	10.0
Electrical conductivity (25 m-1)(25/m)	1.0
Silica, SiO2 (%)	2.1
Alumina, Al2O3 (%)	49.0
Iron, Fe2O3 (%)	11.3
Calcium, CaO (%)	4.6
Magnesium, MgO (%)	12.0
Sulphate, SO4 (%)	6.3
Potash, K2O (%)	7.1
Carbon, C (%)	8.3
Boron, hot water soluble (ppm)	0.075
Water soluble silica, SiO2(ppm)	2.0
Available silica, SiO2 (ppm)	8.0
Zinc (ppm)	300
Copper (ppm)	1258
Manganese (ppm)	1078
Nitrogen	Nil
Phosphorus	Nil

The experiment was conducted in RBD with three replications with the following treatments.

T0 - Control
T1 -Flyash pelleting @ 200 g with gum arabic @10 %.
T2 - Flyash pelleting @ 250 g with gum arabic @10 %.
T3 - Flyash pelleting @ 300 g with gum arabic @10 %.
T4 - Flyash pelleting @ 200 g with rice gruel.
T5 - Flyash pelleting @ 250 g with rice gruel.
T6 - Flyash pelleting @ 300 g with rice gruel.

The following process of seed pelleting with different kinds of pelleting materials was followed.

Process of pelleting:

Seed
↓
Adhesive
↓
Filler (Flyash)

Microbial assessment: Top soil sample (0-15cm) adjacent to the crop rhizosphere were randomly collected using a core borer of 15 cm in depth and 5 cm in diameter. The samples were initially transferred aseptically to the plastic bags that were labelled appropriately and then transported to the laboratory. In the laboratory, fractions of samples were immediately processed for microbial analysis. Culture experiments were conducted for enumeration of soil microbes with the specific recommended media used for the experiment as: a) Nutrient Agar for bacteria as described by Gordon et al. (1973), Rose Bengal Agar for fungi as described by Martin (1950), Kenknight's medium (KN) for actinomycetes as described by KenKnight (1939) and Okon's medium for Azospirillum as described by Okon et al. (1977) and modified by Lakshmi kumari et al. (1980). To estimate the number of soil microflora, counts were calculated on the basis of serial 10 fold dilution technique, using the pour plate methods and replicates of 10 g soil samples, and an appropriate dilution as described by Johnson and Curl (1972).

The experimental soil was analysed for soil physical and chemical parameters. The above treatments were evaluated for biometric and yield parameters viz., plant height, number of branches, number of leaves, dry matter production, number of capsules, number of seeds per capsule, 1000 seed weight and seed yield per plant. All the data were analysed statistically with appropriate tools and expressed as mean values as per the method of Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Establishment of a good seedling stand in the field is an important and foremost need for higher crop yield. This depends largely on the field germination and vigour potential of the seeds used for sowing. Researchers are recommending several pre-sowing seed management techniques with the benefit of invigoration, protection and production (Gopal Singh and Ramarao, 1993). Among the various seed treatments, the physical seed treatments viz., pesticide seed treatment, seed colouring, seed coating and seed pelleting are under wide usage by the seed producers and are normally included as a continuous treatment sequence in post-harvest seed handling techniques.

The populations of bacteria, fungi, actinomyctes and azospirillum were found higher in season I as compared to season II (Table 1). It was found that 250 g flyash pelleting with rice gruel recorded higher populations of bacteria, fungi, actinomyctes and azospirillum followed by 300 g flyash pelleting with rice gruel and the control recorded lower values. Similar reports of increased microbial population with fly ash application have been reported by Ramteke et al. (2017) and Hardeep Singh Sheoran et al. (2014). However, in our experiments, the independent effect of rice gruel or the gum, on population of microbes is not estimated as such treatments were not included. Thus their effects are confounded with that of flyash.

Microbial activity significantly increased with application of fly ash alone or in combination with organic manure and fertilizer as compared to control (Ramteke et al., 2017). These results might be due to the fact that applied organic sources were able to get mineralized rapidly and consequently provided sufficient nutrition for the proliferation of microbes and their activities in terms of soil enzymes. The beneficial effect of fly ash on improvement of soil health in respect of physico-chemical parameters, nutritional status and microbial population may be due to the cumulative effect of improvement in individual physico-chemical characteristics (Hardeep Singh Sheoran et al., 2014).

In fly ash amended soil, the presence and absence of earthworms showed stimulation of soil respiration and microbial activities in the presence of fly ash up to 5% (Pati and Sahu, 2003). Fly ash composted with wheat straw and 2% rock phosphate (w/w) for 90 days had an encouraging effect on chemical and microbiological parameters of the compost and fly ash up to 40-60% did not exert any detrimental effect on either C:N ratio or microbial population (Gaind and Gaur, 2003). Lal et al. (1996) reported that application of fly ash in presence of FYM to an acid soil (Alfisols) resulted in increased microbial population, urease and cellulose activities than alone.

In the present investigation, the fly ash pelleting @ 250g with rice gruel influenced pH (7.56), EC (0.39), organic carbon (4.86), available N (421.69), available P (18.7) and available K (199.7) (Table 2) and all the biometric and yield charecters (Table 3) which was followed by flyash pelleting @ 300 g with rice gruel, when compared to other treatments. Similar results have been reported by Deepa Katiyar et al. (2012) and Baskar et al. (2017) in ground nut. Khan et al. (1996) reported increase in available P and K status in soil and they attributed it to the P and K content of fly ash. Flyash can be used as a soil ameliorate that may improve physical, chemical and biological properties of the degraded soils and is a source of readily available plant micro-and macro nutrients. Flyash has great potentiality in agriculture due to its efficacy in modification of soil health and crop performance (Gayatri Sahu et al., 2017). Fly ash can be used in combination with chemical fertilizer and organic carbon to get additional benefits in terms of improvement of soils physical characters for increased yield of crops (Panda and Biswal, 2018).

From the present investigation, it was found that the sesame seeds pelleted with flyash @ 250 g with rice gruel recorded higher values for biometrical traits viz., plant height (106.4 cm), number of branches (6.66), number of leaves (119.3), dry matter production (21.035 g), number of capsules (89.7), number of seeds per capsule (81.23), 1000 seed weight (2.56 g) and seed yield per plant (12.27 g) followed by the flyash @ 300 treatment. Flyash contains sufficient concentration of micro and macronutrients like calcium, iron, manganese, boron, nitrogen, phosphorus, zinc and potassium which can be better utilized in agriculture, as fertilizers (Hodgson and Buckley, 1975; Carlson and Adiriano, 1991). These micronutrients would have helped to increase the rate of cell division, cell elongation and availability of these nutrients which could be responsible to increase plant height. The probable reason might be the activation of enzymes by the micronutrients which resulted in elongation of seedling measurements and their biomass production (Patagundi, 1997). The micronutrients such as zinc, boron, manganese and iron present in flyash are highly essential for activation of enzyme system related to seed viability and vigour as revealed by several researchers (Patil et al., 1993). The Zn and Mn present in the flyash by activating physiological and biochemical processes, would have helped to increase dry matter production.

The Zn and Mn present in the flyash could have helped in enhancing physiological and biochemical processes thereby increasing shoot and root growth. Root length was increased up to, 50% with 50% ash application in black cotton soil and 110% in alluvial soil respectively. The shoot length was increased by maximum 22.2% with 25% ash application in black cotton soil and 33.3% in alluvial soils respectively (Kalpana kumar and Dubey, 2003). The enhanced root growth with ash application might be due to the modification in the soil physical conditions, mainly the retention, release and transmission behavior for water and nutrient availability (Kesh et al., 1998).

All these micronutrients present in the flyash would have increased the nutrient status of the plant, helped in translocation of assimilates resulting in increased seed weight and final seed yield. Increased yield with micronutrients could be due to enhanced availability and translocation of nutrients resulting in increased capsule number, seed number, and seed weight. Increased yield due to Zn present in flyash might be due to reduced flower drops, increased capsule set. Similar results have been reported by Prakash et al. (2014) in sesame and Prakash et al. (2014) in okra.

To conclude, seed pelleting with fly ash @ 250 g with rice gruel influenced various soil parameters, increased soil microbial populations of bacteria, fungi, Actinomycetes, Rhizobium, Azospirillum and seed yield in sesame, when compared to other treatments.

Table 1 Effect of flyash seed pelleting on rhizosphere population in sesame

Treatment	Bacterial population (X 106cfu)		Fungi (X 104cfu)		Actinomycetes (X 104cfu)		Azospirillum (X 104cfu)	
	S1	S2	S1	S2	S1	S2	S1	S2
T0	6.85	6.87	8.09	7.93	8.23	8.27	8.41	8.45
T1	7.37	7.48	8.11	8.33	8.43	8.47	8.49	8.54
T2	7.47	7.41	8.30	8.40	8.47	8.97	8.72	8.75
T3	7.36	7.39	8.41	8.41	8.43	8.57	8.83	8.81
T4	7.43	7.60	8.52	8.29	8.37	8.86	8.89	8.94
T5	7.58	7.82	8.81	8.89	8.70	9.21	9.15	9.25
T6	7.50	7.63	8.60	8.73	8.63	9.10	9.02	9.09
CD(0.05)	1.41	1.11	1.242	1.153	1.66	1.51	1.59	1.64

Table 2 Effect of flyash seed pelleting on soil parameters in sesame

Treatment	Soil pH		EC		Organic Carbon		Available N		Available P		Available K	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
T0	7.60	7.42	0.18	0.28	3.62	4.50	135.37	416.30	25.0	18.1	202.6	182.3
T1	7.55	7.45	0.22	0.27	3.67	4.83	135.30	417.16	23.9	18.5	203.3	187.3
T2	7.50	7.47	0.21	0.35	3.62	4.84	134.21	417.20	24.2	18.2	202.3	199.0
T3	7.52	7.46	0.22	0.33	3.69	4.82	135.22	416.35	23.6	18.4	203.2	189.6
T4	7.53	7.49	0.23	0.38	3.83	4.82	134.20	419.83	23.7	18.3	204.3	189.3
T5	7.52	7.56	0.23	0.39	3.81	4.86	134.15	421.69	23.6	18.7	205.3	199.7
T6	7.50	7.52	0.24	0.37	3.82	4.83	135.10	421.30	23.5	18.6	203.9	199.1
CD(0.05)	1.31	1.30	0.001	0.003	1.10	1.36	18.7	21.4	3.4	2.8	15.6	11.6

Table 3 Effect of flyash seed pelleting on growth parameters in sesame

Treatments	Plant height (cm)	Number of branches	Number of leaves	Dry matter production (g pl-1)	Number of capsules	Number of seeds per capsule	1000 seed weight (g)	Seed yield per plant (g)
T0	92.9	3.33	98.33	16.359	76.7	62.67	2.43	9.98
T1	96.1	4.66	106.1	17.755	79.3	71.67	2.45	10.16
T2	100.5	5.33	116.7	19.772	85.3	76.33	2.46	11.21
T3	99.3	4.33	110.7	18.921	84.7	74.33	2.48	10.48
T4	97.3	5.33	112.3	18.343	84.0	75.11	2.51	11.05
T5	106.4	6.66	119.3	21.035	89.7	81.23	2.56	12.27
T6	104.3	5.86	115.7	19.773	87.0	78.67	2.52	12.06
CD(0.05)	8.69	0.11	9.8	2.77	6.43	1.43	1.03	0.81

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Status of sunflower crop in Andhra Pradesh-Reasons for decline and measures to revive

K VENKATARAMANAMMA*, S NEELIMA, D LAKSHMI KALYANI AND S JOSEPH REDDY

Regional Agricultural Research Station, Acharya N G Ranga Agricultural University, Nandyal-518 502, Andhra Pradesh

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ABSTRACT

A survey was conducted to know the reasons for decline in area of sunflower and measures to revive the crop in six districts of Andhra Pradesh viz., Kurnool, YSR Kadapa, Prakasam, Ananthapuramu, Nellore and Chittoor districts. Among the different reasons explained, marketing problems, lack of stable yield in hybrids and diseases like necrosis are the major problems which prompted farmers to shift to other remunerative crops like cotton, Bengal gram, black gram, maize, red gram, groundnut and others in different districts of Andhra Pradesh based on their suitability. To bring back its cultivated area again some of the measures like development of promising hybrids, good marketing facilities, proper extension services and mechanization etc are needed.

Keywords: Bengalgram, Cost of cultivation, Cotton, Decline, Maize, Sunflower

Sunflower is one of the major oil seed crops grown in India and world. Among other countries, Ukraine is the top producer with 11.0 MT followed by Russia with a production of 10.6 MT and these two countries contributed for half of the production in the world (World Atlas.com). In India sunflower crop is cultivated in an area of 2.86 lakh ha with a production of 2.11 lakh tonnes with a productivity of 738 kg/ha (Anonymous, 2019). Among the sunflower cultivated states, major area was in Karnataka, Andhra Pradesh and Maharashtra. However, the cropped area declined year by year since 2005-06 (Fig.1). From the highest acreage of 23.4 lakh ha (source: Ministry of Agriculture) in the year 2005-06, the area which has reduced by 88%, over a period of one decade. As far as Andhra Pradesh is concerned, this crop was cultivated in an area of 9000 ha, with a production of 11000 ton, and productivity of 1222 kg/ha (Anonymous, 2019). To bring back its area again, Indian Institute of Oilseeds Research, Hyderabad conducted a survey through AICRP centres of sunflower to know the reasons for declining area. Though, this crop is grown traditionally in certain parts of Andhra Pradesh, most of the farmers shifted to other crops owing to the problems in sunflower cultivation. A study was conducted in six districts of Andhra Pradesh (declined area is represented in Fig.2) with the objectives of Conducting a survey to understand the reasons for declining traditional cropped area of sunflower, Analysing the reasons for choosing other remunerative crops in place of sunflower and to delve into the possible Measures to be adopted to revive the sunflower crop.

MATERIALS AND METHODS

The present survey was carried out by AICRP sunflower scheme at RARS, Nandyal, Andhra Pradesh from the farmers of six major sunflower growing districts such as Kurnool, YSR Kadapa, Ananthapuramu, Chittoor, Prakasam and Nellore during 2018. Special interaction was made with seed growers, seed certification agencies and department of Agriculture, as they are the source of seed and have experience with crop growth and they may provide more information about area declining and suggestions to bring back the area. Among the six districts, based on the information available, major cultivated area of sunflower was found in Kurnool, YSR Kadapa, Ananthapuramu and Prakasam districts and less area was observed in Nellore and Chittoor districts (Table 1).

Table 1 Major sunflower grown districts of Andhra Pradesh

District name	2005-06 (‘000 ha)	2012-13 (‘000 ha)	2017-18 (‘000 ha)
Kurnool	180	30.6	2
YSR Kadapa	78	49.6	3
Ananthapuramu	49	10.6	2
Prakasam	28	16.0	0
Nellore	16	2.7	0
Chittoor	3	1.0	1

Source: Directorate of Economics and Statistics, Hyderabad.

The sowings were usually taken up by farmers during kharif, rabi and summer seasons in Kurnool and Kadapa districts, Ananthapuramu and Chittoor districts and in Nellore, Prakasam districts, in rabi season only. Based on the sunflower area cultivated, 10 mandals each from Kurnool, Kadapa, 6 mandals from Prakasam, 5 mandals from Ananthapuramu, 4 mandals each from Nellore and Chittoor districts were selected for the survey. Three villages were selected randomly from each mandal and about 10 to 15 sunflower farmers from each village participated in the survey. Data on cropping season for sunflower, cultivated hybrids, economics, and reasons for not growing sunflower, extension, market related problems, social causes, replaced

*Corresponding author's E-mail: kvrag84@gmail.com

crops, reasons for replacement, advantage of replaced crops and suggestions for reviving of this crop etc. were collected. Input costs including labour were calculated as per the existing price and standard economics formulae were used for all the calculations.

RESULTS AND DISCUSSION

After collecting the data, the reasons for declining of sunflower cropped area was divided into major, minor and other reasons (Table 2).

a. Major determinants: Among the major reasons specified, 90-100% of farmers informed that low yield levels and lower remunerative price were the major setbacks for sunflower crop cultivation. Among them, 70-80% of farmers expressed uncontrollable necrosis disease, erratic rainfall, poor seed setting and 80% of farmers expressed severe damage caused by birds in isolated fields and 50 to 70% of farmers expressed non availability of quality seed and also improper flower head opening as the reasons for shifting to other crops.

b. Minor determinants: Among the minor reasons, unfavourable weather conditions (20 to 40% of the farmers), high incidence of diseases like Alternaria leaf spot, head rot and pests during crop period are noteworthy. Wild boar was major problem in certain pockets of Kurnool, Kadapa, Ananthapuramu and Chittoor districts. Less than 20 per cent of farmers stated poor mechanization, one time seed set and multi heads and non suitability of crop stocks as cattle feed unlike in groundnut, maize as the reasons for non cultivation of sunflower.

Officials from Department of Agriculture, Seed Certification Officers and Scientific Community opined that closer spacing without thinning, failure to apply sulphur containing fertilizers, lack of proper supervision on seed production channel, less population of bees (pollinators), lack of subsidy for inputs and lack of awareness on management as major factors for decline in area of sunflower.

Various reasons like low prices at harvesting time, non implementation of MSP, difficulty in storage till prices improved, lack of access to improved seed, high cost of cultivation, low yields due to mono cropping of sunflower were some of the reasons expressed by farming community. Singha et al. (2014) also reported high input cost, non availability of improved seed at right time, proper knowledge of pest and diseases and poor extension services as the major constraints for sunflower cultivation in Karnataka.

The major sunflower hybrids cultivated since 15 years by farmers and the cost of cultivation, yields realized and the gross returns obtained are furnished in Table 3. The estimated cost of cultivation increased from Rs.15000-18000 in 2000 to 35000-40000 Rs/ha in 2015. Yields declined abruptly from 15 to 20 q/ha to as low as 7.5 to 12 q/ha from 2000 to 2015.

Shifting to remunerative crops: Due to increased cost of cultivation and less returns of sunflower crop, farmers shifted to profitable crops of their own choice as replacement to sunflower crop (Table 4). Cotton, Bengal gram, black gram, maize and groundnut are the major crops that replaced sunflower, while specifically, in Kadapa - hybrid seed production of millets, black gram, groundnut, bengal gram; in Ananthapuramu - cotton, bengal gram, groundnut, jowar; in Prakasam - black gram and red gram; in Nellore - Cotton, hybrid jowar and in Chittoor - groundnut, tomato and other vegetables replaced the sunflower crop.

Over the years from 2005-06 to 2017-18, the decline in area of sunflower crop was observed as 97.8% in the surveyed districts of Andhra Pradesh (Table 5). The area of black gram, maize, cotton, bengal gram and red gram increased in these districts by 93.93%, 75.24%, 53.47%, 56.4%, 45.66%, and 38.5% respectively. As per the information available, the decline in cultivated area of sunflower matches with the increased area under cotton, bengal gram, black gram, red gram and maize and it was also observed that area of groundnut was also less compared to previous years in the four districts viz., Ananthapuramu, Kurnool, Kadapa and Chittoor because of various reasons and probably some of these crops also replaced groundnut.

Reasons for opting other crops as an alternative to sunflower: Changing soil, water and rainfall pattern in the districts of Andhra Pradesh made the conditions more suitable for other crops. Farmers opted cotton, bengal gram, black gram, maize and red gram as an alternative crops to sunflower as the risk involved with these crops is less because of availability of quality seed, stability in yield and market prices.

Additional advantage with crops like black gram, maize, red gram and groundnut is the availability of crop residue as feed for animals and poultry. Introduction of Bt cotton encouraged the farmers to grow cotton as an alternate crop due to less incidence of bollworms, which was a major problem for cotton cultivation. Bengalgram being a rabi crop, grown on receding soil moisture is amenable for mechanization which is another major reason to choose it as an alternate crop. Red gram was preferred as a rainfed crop due to its innate ability to tolerate drought compared to sunflower in Prakasam district.

Shifting from one crop to the other in any area or state is a common phenomenon. In the traditional rice area of Haryana due to decline in ground water, maize emerged as an alternate crop as it requires only 2 to 3 irrigations during crop season and also high yielding varieties of this crop are made available to farmers (Yadav et al., 2011).

Similar results were reported by Singha and Naphade (2012) in Karnataka. Habib et al., (2017) reported that commercial crops tobacco and sugar cane replaced sunflower due to non availability of quality seed, fluctuation in marketing price and poor extension services.

Economics of alternate crops over sunflower: Cultivation of Bengal gram as a rabi crop dependent totally on receding soil moisture with no risk and moderate fluctuation in market prices emerged as an alternate crop to sunflower during recent years. Though the cost of cultivation of cotton is high, higher yields and less risk factors resulting in higher gross returns per ha (Table 6) made the farmer to choose this crop over sunflower. Red gram being drought tolerant coupled with stable and assured market price has been promoted as an alternative to sunflower.

Farmers prefer Maize crop because of price stability and the various value added products that can be made. In Chittoor district, tomato and other crops were found remunerative and alternate to sunflower.

Table 2 Reasons for declining of sunflower cropped area as perceived by farmers and officials

Reasons	% of farmers opinion	Remarks
A. Major		
Low yield levels	98	
Lack of remunerative price	100	Marketing problems
Poor seed setting	70	Un-known reasons
Necrosis virus damage	75	Systemic and kills whole plant
Birds damage (especially parrots)	80	When grown in isolated patches
Erratic rainfall pattern	80	Late/early onset of monsoons/ excess of moisture/ drought.
Spurious seed	70	Quality seed not available
Closing of floral heads at maturity stage	50	Might be virus problem
B. Minor		
Multi heads in cultivating hybrids	20	During stress conditions
Wild boar problem	40	Particularly Atmakur, Nandikotkur of Kurnool dt, parts of Anantapur, Kadapa and Chittoor districts.
Crop requires more inputs such as fertilizers and plant protection chemicals	20	Lack of awareness on fertilizer management
Continuous cultivation leading to poor yields and less productive soils	20	Mono cropping
Unfavourable weather conditions	30	High temperatures during flowering. Effect of mogali etc.
Diseases like Head rot, Alternaria leaf spot and powdery mildew diseases	20	Under continuous drizzling conditions, head rot and Alternaria leaf spot diseases becomes more severe.
Lack of fodder value	10	Like Groundnut, Maize etc
Lack of value added products	5	Like Groundnut, Maize etc
Sets seed one time only	5	Multiple pickings in cotton, castor etc.
Labour problem for various operations during crop growth period.	15	During peak periods it is problem
Poor mechanization	15	Only threshing machine is available
Deer problem	--	Location specific

Measures to revive the sunflower crop in the traditional area of Andhra Pradesh: Based on the present survey and analysis of the data, several measures need to be taken up to revive sunflower crop in the traditional area of Andhra Pradesh, these include development of promising hybrids with stable yield under fluctuating weather conditions with good seed set and also to overcome the problems like premature head opening; measures to be taken up by the public sector agencies to fix remunerative market price and ensure implementation of the same by establishing effective procurement chain; development of hybrids resistant to diseases like necrosis and pests; central government should take immediate measures to stop or reduce sunflower imports, thereby increasing the market price for local farmers; proper vigilance on seed production chain to ensure the availability of good quality seed; use of methods like fertigation to increase productivity of sunflower; sensitizing the farmers about use of protein rich thalamus (14%), as bird and cattle feed; frequent visits of extension personnel during crop season and alerts through various media like radio, television and mobile related to crop management; strengthening research on value added products; adoption of mechanization in sowing and inter cultural operations and plant protection to reduce cost of cultivation and timely control of weeds and diseases; bringing public awareness on health benefits of sunflower oil; provision of subsidy for seed to farmers; adoption of best management practices for achieving higher yields. In support of this, Habib et al. (2017) suggested that sunflower cultivation was feasible in some areas of Pakistan, only when the government provided more economic incentives and appropriate market structure for sunflower output. With slew of measures suggested above, we feel that the traditional area of cultivation of sunflower could be restored in Andhra Pradesh.

It is evident from the reasons mentioned above, that a farmer always looks for a crop that gives high production, productivity in both favourable and unfavourable weather conditions, demands less operational costs, and attracts higher remunerative price. So there is no other alternative than to provide all these to bring back sunflower to its past glory.

Table 3 Cost of cultivation particulars of sunflower in previous years

Year	Name of the hybrid	Cost of cultivation (₹/ha)	Yield (q/ha)	Gross monetary returns (₹)
2000	SB-275, SB 272, Mahyco-17, Mahyco- 7, Kaveri-618	15000-18000	15-20	30000-38000
2005	SB-275, ITC, Kargil, Ganga Kaveri	25000-28000	17.5-20	43750-48000
2010	SB-275, Kaveri Champ, Nidhi, Super Raja, Penna, Kaveri-678	33000- 35000	12.5-15	37500-45000
2015	Pioneer, Ankur, NK Armony	35000-40,000	7.5 – 12	23000-36000

Table 4 Crops which replaced sunflower crop in different districts of Andhra Pradesh

District name					
Kurnool	Kadapa	Ananthapuramu	Nellore	Prakasam	Chittoor
Cotton	Bengal gram	Groundnut	Maize	Bengal gram	Groundnut
Bengal gram	Groundnut	Cotton	Hybrid jowar	Maize	Tomato and other vegetables
Maize	Black gram	Jowar	Bengal gram	Black gram	--
Black gram	Hybrid Maize/Sajja/ Jowar seed production	Bengal gram	Cotton	Red gram	--
Others like Onion, Jute, Korra etc.	Sesamum/ Melons	Others like Korra, Castor etc.	--	--	--

Table 5 Area particulars of replaced crops in six districts in different years of Andhra Pradesh

Crop	2005-06 ('000 ha)	2017-18 ('000 ha)	Area increase or decrease ('000 ha)	% of increase or decrease
Sunflower	368	8	-360	-97.82
Cotton	160	367	+207	+56.4
Bengal gram	263	484	+221	+45.66
Black gram	4	66	+62	+93.93
Maize	25	101	+76	+75.24
Red gram	174	241	67	+38.5

Source: Directorate of Economics and Statistics, Hyderabad, Vijayawada

Table 6 Economic particulars of sunflower and replaced crops

Particulars	Sunflower	Cotton	Groundnut	Bengalgram	Maize	Redgram	Tomato
Cost of cultivation (₹/ha)	20,000-25,000	62,500 -75,000	25,000-32,500	30,000-37,500	50,000-55,000	25,000-28,000	2.5-4 lakh
Yield (Q/ha)	10-15	23-30	25-30	10-20	62.5-75	7.5-23.5	25.00
Gross monetary returns (₹/ha)	30,000-45,000	103500-140000	60000-100000	40000-80000	81250-97500	33750-105750	3 lakh to 8 lakh
Crop related risks (drought, late/early onset of rains)	More	Less	Moderate	Less	Moderate	Moderate	Moderate
Market related risks (Prices /marketing)	More	Moderate	Moderate	Moderate	Moderate	Moderate	High

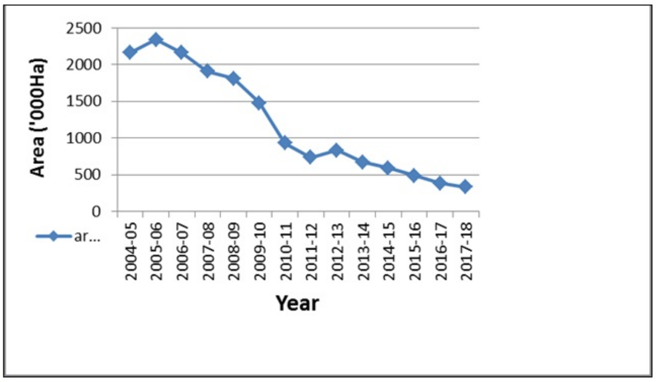

Fig.1. Area particulars of sunflower crop in India from 2004-05 to 2017-18

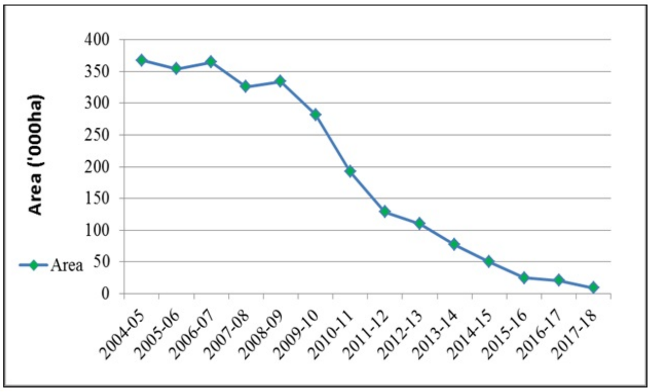

Fig. 2. Area particulars of sunflower crop in Andhra Pradesh from 2004-05 to 2017-18

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Impact of FLDs on the knowledge level of mustard production technology and yield between beneficiary and non-beneficiary farmers

S R MEENA*, G S BANGARVA AND I M KHAN

S K N College of Agriculture, Sri Karan Narendra Agriculture University, Jaipur - 303 329, Rajasthan

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ABSTRACT

Indian mustard is an important rabi oilseed crop of India. Rajasthan is the leading producer of the crop. In order to enhance the productivity of the crop, the KVKs and DRMR have conducted the frontline demonstrations with recommended package of practices. The impact of the FLDs in terms of increase in knowledge level of farmers and the yields were assessed in this study. The study was conducted in Bharatpur division and the results indicated higher knowledge scores and higher yields scores of the beneficiary farmers as compared to non-beneficiary farmers indicating the impact of conduct of FLDs in the region.

Keywords: Bharatpur, FLDs, Impact, Knowledge level, Mustard

Indian mustard [Brassica juncea (L.) Czern & Coss.] is grown over an area of 6.34 m ha with a production of 7.82 m t and productivity of 1233 kg/ha and contributes 80 per cent of total rabi oilseeds production of India. Rajasthan is the leading producer of mustard in the country. Therefore, the enhancement of productivity in Rajasthan is critical for increasing the overall production of oilseed in the country. The state contributed nearly half of the total production of the crop in the country. The entire state except a few areas falls within the major production zone of rapeseed-mustard crop in the country. However, the productivity level of the leading producer state of rapeseed mustard is less than that of states like Haryana and Gujarat. Considering the large area under the crop in the state, a small increase in average state productivity can significantly increase the overall production in the country (DOR, 2014). Bharatpur division comprising of five districts (Alwar, Bharatpur, Dholpur, Karoli and Sawai-madhopur) of Rajasthan is the largest mustard growing region covering 40 per cent of the total area of the State (DOR, 2014) with productivity of more than national average. The region has potential to further enhance the productivity as evidenced from the frontline demonstrations conducted in the state by the KVKs and Directorate of Rapeseed Mustard (DRMR). In order to enhance the productivity, the capacity building of farmers in terms of knowledge on recommended production technology is necessary. Hence, the present study was conducted to assess the level of knowledge on recommended mustard production technology of the beneficiary (FLDs farmers) and non-beneficiary farmers in Bharatpur division.

MATERIALS AND METHODS

Five Krishi Vigyan Kendra's (KVKs) from Bharatpur Region of Rajasthan, which have conducted FLDs on mustard were selected. From each of the selected KVKs, 25 beneficiary farmers and 25, non-beneficiary farmers (Table 1) were selected using simple random sampling without replacement. Thus, a total of 250 respondents were interviewed with the help of a structured interview schedule prepared for the purpose.

Table 1 Selection of Krishi Vigyan Kendras and respondents

Division	KVK	No. of Respondents	
		Beneficiaries	Non-beneficiaries
Bharatpur Region	Alwar (H)	25	25
	Bharatpur (H)	25	25
	Dholpur (M)	25	25
	Karoli (H)	25	25
	Sawai-madhopur (H)	25	25
Total		125	125

The data were tabulated, frequencies, percentages, mean and S.D, were worked out and appropriate statistical tests such as 'z' test was used. The knowledge of respondents was measured by administering a knowledge test. Twelve practices were considered to assess the level of knowledge. Mean percent scores (MPS) and knowledge gaps (KG) of each major practice were computed.

RESULTS AND DISCUSSION

Knowledge level of beneficiary and non-beneficiary farmers on recommended package of practices for mustard production.

Distribution of the beneficiary and non-beneficiary farmers according to their knowledge level: Based on the knowledge scores, respondents were categorized into three groups of low, medium and high knowledge level categories

Corresponding author's E-mail: abhishek.mermat@gmail.com

using mean scores (73.6) and standard deviation (4.65). The number of respondents and corresponding percentages are presented in table 2. It can be observed that, in total, about 50 per cent of the farmers (124) had medium level of knowledge regarding recommended mustard production technology followed by high (29.2%) and low (21.2%).

Majority (51.2%) of the beneficiary farmers were in medium level of knowledge followed by high (26.4%) and low (22.4%) level of knowledge on recommended mustard production technology. In case of non-beneficiary farmers, 48, 32 and 22.4 per cent of respondents were in medium, high and low level of knowledge categories respectively. These findings are in compliance with the findings of Singh and Narpat (2004), Singh and Sharma (2005), Ashiwal (2006), Tambade (2007), Ashiwal et.al. (2008), Singh et.al. (2008), Chander et.al. (2009), Prasad (2011), Sharma et.al. (2011), Badhala (2012), Balai et.al. (2012), Rai et.al. (2012), Mandavkar et.al. (2013), Amit et.al. (2016), Meena and Monika (2016) and Rajpal et.al. (2016).

Item-wise knowledge level of respondents: The practice-wise knowledge level of the beneficiary and non-beneficiary farmers were measured in terms of mean percent score and knowledge gaps. Among the 12 recommended practices of mustard production, farmers had highest level of knowledge on weed management (87.20 MPS) followed by soil and field preparation (84.40), physiological aspects/practices (83.29 MPS), seed rate and recommended spacing (82.08 MPS) and time of sowing (81.25 MPS). Highest knowledge gap score of 40.7 was observed for high yielding varieties followed by seed treatment (41.2) and soil treatment (39.89, Table 3).The practice-wise knowledge of beneficiary and non-beneficiary farmers is presented in Table 3.

The findings correspond with the findings of Singh (2004), Ashiwal (2006), Tambade (2007), Ashiwal et al. (2008), Singh et al. (2008), Chander et al. (2009), Prasad (2011), Sharma et al. (2011), Badhala (2012), Rai et al. (2012), Mandavkar et al. (2013) and Rojh et al. (2016) and established that beneficiary farmers had higher knowledge than the non-beneficiary farmers regarding mustard production technology and also similar trends of knowledge level between beneficiary farmers and non-beneficiary farmers.

The higher level of knowledge amongst the beneficiary farmers in comparison to the non-beneficiary farmers with regard to recommended mustard production technology was due to the efforts of institutions like as DRMR and KVKs. In the process of conducting FLDs, these institutions interacted frequently with farmers, provided necessary guidance, literature and training to the beneficiary farmers, which resulted in higher knowledge scores among beneficiary farmers as compared to non-beneficiary farmers. Further, the yield levels obtained by the beneficiary farmers were more than that of non-beneficiary farmers indicating the impact of the technology (Table 4). The score for the yield level were higher (164.02) and significant (z =13.11, p = 0.01) for beneficiary farmers as compared to non-beneficiary farmers (141.40). Thirty five per cent of the beneficiaries were in high yield score category as compared to 25.6 per cent of non-beneficiaries. The distribution of respondents based on yields score is presented in Table 4. The findings are in congruity with the findings of Singh (2004), Sachan and Sharma (2005), Ashiwal (2006), Singh et al. (2007), Tambade et al. (2007), Chander et al. (2009), Badhala and Jat (2012), Bairwa et al. (2012), Balai et al. (2012), Meena et al. (2012), Rajeev et al. (2013), Sarma et al. (2014) and Jat et al. (2015).

From this study it could be concluded that the study there were clear differences among beneficiary and non-beneficiary farmers with respect to the knowledge on mustard production technology. The high knowledge gap on improved varieties and seed treatment indicated that there has to be concerted efforts to create awareness on these aspects and awareness programmes/campaigns have to be organized for popularizing these low-cost technologies varieties to achieve higher productivity. The yield levels of beneficiary farmers were higher compared to non-beneficiary farmers showing the impact of FLDs. In order to further improve the productivity level of mustard in Bharatpur division, more FLDs, involving the Department of Agriculture, are to be organized to bring more people inside the umbrella of farmers following improved agri-technologies.

Table 2 Distribution of the respondents based on knowledge on recommended mustard production technology

Knowledge level	Beneficiary (N=125)		Non-beneficiary(N=125)		Total (N=250)	
	F	%	F	%	F	%
Low (<68.95 score)	28	22.40	25	20.00	53	21.20
Medium (70 to 78 score)	64	51.20	60	48.00	124	49.60
High (>78.25 score)	33	26.40	40	32.00	73	29.20
Total	125	100.00	125	100.00	250	100.00

Mean =73.60; S.D. = 4.65; F= Frequency; %= Percentage

Table 3 Item-wise knowledge of beneficiary and non-beneficiary farmers

Item	Beneficiary (N=125)		Non-Beneficiary (N=125)		Total (N=250)	
	MPS	KG	MPS	KG	MPS	KG
High yielding varieties	60.42	39.58	58.06	41.94	59.24	40.76
Soil and field preparation	89.60	10.40	79.20	20.80	84.40	15.60
Soil treatment	63.08	36.92	57.14	42.86	60.11	39.89
Seed treatment	60.00	40.00	57.60	42.40	58.80	41.20
Time of sowing	88.89	11.11	77.78	22.22	81.25	18.75
Seed rate and recommended spacing	84.16	15.84	80.00	20.00	82.08	17.92
Fertilizer application	71.81	28.19	61.11	38.89	66.46	33.54
Irrigation management	80.00	20.00	60.00	40.00	70.00	30.00
Weed management	90.00	10.00	84.40	15.60	87.20	12.80
Plant protection measures	67.55	32.45	62.50	37.50	65.02	34.98
Physiological aspects /practices	88.80	11.20	77.78	22.22	83.29	16.71
Harvesting/threshing and storage	80.00	20.00	60.00	40.00	70.00	30.00
Over all	77.03	22.97	67.96	32.04	72.32	27.68

MPS=Mean Per cent Score; KG= Knowledge Gap's; rs = Rank correlation; **Significant at 1% level

Table 4 Distribution of respondents based on yield level

Level of yield	Beneficiary (N=125)		Non-beneficiary (N=125)		Total (N=250)	
	F	%	F	%	F	%
Low (<143.06 score)	29	23.20	37	29.60	66	26.40
Medium (144 to162 score)	52	41.60	56	44.80	108	43.20
High (>162.34 score)	44	35.20	32	25.60	76	30.40
Total	125	100.00	125	100.00	250	100.00
	Mean	SD	Mean	SD	Z value	
Yield score	164.02	14.61	141.40	12.60	13.11**	

Mean =152.70; SD = 9.64

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Impact of front line demonstrations on improved management practices in groundnut and sesamum

P VENKATA SUBBAIAH[1] AND V JYOTHI

Agricultural College, Acharya NG Ranga Agricultural University, Bapatla-522101, Andhra Pradesh

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ABSTRACT

Groundnut and sesamum are two important oilseed crops grown in Andhra Pradesh. Adoption gaps were identified in both the crops indicating the need for demonstration of improved crop management practices. In groundnut, the variety Kadiri 7 bold was demonstrated in kharif and rabi seasons while in sesamum, the variety YLM 66 was used for demonstration during summer. Along with the varietal introduction the whole package of improved management practices were also demonstrated. A total of 40 FLDs each in groundnut and sesamum were organized for two consecutive years 2016-17 and 2017-18 in Krishna district, Andhra Pradesh. In kharif groundnut, highest yield of 41.75 q/ha was recorded in the demonstration fields with an average yield of 36.95 q/ha while in rabi groundnut, the highest yield of 41.63 q/ha was recorded in demonstration plot with an average yield of 40.77 q/ha as against farmers practice of growing local varieties gave an average yield of 30.00 q/ha in both the seasons. In sesamum, highest yield of 15.20 q/ha was recorded in the demonstration fields with an average yield of 15.00 q/ha as against farmers practice of growing local varieties gave an average yield of 10.40 q/ha. Paired t test of the economics of demonstrations and farmers practices showed significant and positive difference between improved practice and farmers practice.

Keywords: Demonstrations, Oilseeds, Management Practices

Groundnut and sesamum are two important oilseed crops grown in Andhra Pradesh. Groundnut is cultivated both in kharif and rabi while sesamum is cultivated in summer under irrigated conditions for additional income. In both the crops, it was observed that farmers are still growing the varieties released decades back because of which the production and productivity are relatively low when compared with that of the recently released varieties.

In order to create awareness and show the productivity potential and profitability of improved varieties, Frontline Demonstrations (FLDs) were conducted in the two crops. In groundnut, the demonstrations were taken up with high yielding variety Kadiri 7 Bold. The variety is bold seeded with dormancy for 40 days, tolerant to trips, suitable for kharif and rabi, having yield potential upto 50 q/ha. In sesamum, high yielding variety YLM 66 was demonstrated under FLDs using cluster approach. YLM 66 has light brown colour seed, tolerant to powdery mildew and leaf spot with crop duration of 75 days and potential yield of 16 q/ha. In the FLDs, along with varietal introduction of new varieties, the whole package of improved practices was demonstrated to farmers during 2016-17 and 2017-18 consecutively and its impact was assessed.

MATERIALS AND METHODS

A total of 80 FLDs each in groundnut and sesamum were organized in two consecutive years (2016-17 and 2017-18) in Jaggaiahpet, Vastavai and Penugranchiprolu mandals of Krishna district in Andhra Pradesh. The soils, where demonstrations were conducted were red chalka. The rainfall recorded in the demonstration area during 2016-17 was 500 mm and in 2017-18 was 520 mm. Along with the varietal introduction the whole package of improved management practices were also demonstrated as presented in Table 1. Farmers practices were compared with improved management practices taking a sample size of 40 farmers in each crop and adoption gaps were identified. The gaps were categorized into three groups as no gap given a score of 1, partial gap given a score of 2 and full gap given a score of 3.

Adoption gap index was calculated using the formula given by Dubey et al., (1981). Adoption gap index is the percent deviation in farmer's practices as compared to the improved practices.

$$\text{Adoption Gap Index} = \frac{(R-A)}{R} \times 100$$

Where, R=Total no. of improved practices,
A=No. of improved practices actually adopted by the farmer

Yield parameters of both demonstrations and check involving farmers practices were recorded. Using the yield parameters extension gap, technology gap, yield gap, technology index were calculated as suggested by Samui et al. (2000).

Extension Gap (q/ha) = Demonstrated Yield - Yield Under Existing Farmers Practice
Technology Gap (q/ha) = Potential Yield - Demonstration Yield
Yield Gap (%) = (Extension Gap/Yield Under Existing Farmers Practice) x 100
Technology Index (%) = Technology Gap/Potential Yield x 100

Corresponding author's E-mail ID: venkat.076@gmail.com

Economics of the demonstrations and check were recorded. Based on economics additional cost, effective gain, additional returns, incremental B: C ratios were calculated.

Additional cost (₹)= Demonstration Cost (₹)-Farmers Practice Cost (₹)
Additional returns (₹) = Demonstration returns (₹) - Farmers Practice returns (₹)
Effective gain (₹) = Additional Returns (₹)-Additional cost (₹)
Incremental B:C ratio = Additional Returns/Additional Cost

Paired t test was applied to know if there exists a significant difference in the economics of demonstration and check.

RESULTS AND DISCUSSION

In a survey conducted among 40 respondents in each of the crops, the results revealed that groundnut and sesamum showed similar adoption gaps. Full gap was identified with adoption of variety, seed treatment and plant protection. Partial gaps were identified with fertilizer management and weed management. While no gaps were identified with land preparation, sowing time, seed rate, irrigation scheduling and harvesting as presented in Table 1.The distribution of the respondents based on adoption gaps revealed 30.00 per cent of them in both groundnut and sesamum were observed with high adoption gaps, while 20.00 per cent were observed in medium adoption gaps category while the remaining 50.00 per cent had no adoption gaps as presented in Table 2. The farmers in high and medium adoption gap categories need to be educated on improved practices of crop management to fill the adoption gaps.

The adoption gap index was calculated and found to be 50.00 per cent in both groundnut and sesamum which indicates that there is urgent need for technological interventions by the scientists. Hence, it was planned to take up the frontline demonstrations in farmers fields using cluster approach.

In kharif groundnut, highest yield of 41.75 q/ha was recorded in the demonstration field, while the lowest yield was 36.97 q/ha with an average yield of 36.95 q/ha. In rabi groundnut, highest yield of 41.63 q/ha was recorded in the demonstration fields, while the lowest yield was 39.63 q/ha with an average yield of 40.77 q/ha. The check variety recorded an average yield of 30.00 q/ha in both kharif and rabi seasons as presented in Table 3. In sesamum, highest yield of 15.20 q/ha was recorded in the demonstration fields, while the lowest yield recorded was 14.80 q/ha with an average yield of 15.00 q/ha. The check variety recorded an average yield of 10.40 q/ha. Based on the yield details extension gap, technology gap, yield gap were calculated and represented in Fig 1.

The extension gap was 6.95 q/ha in kharif groundnut, 10.77 q/ha in rabi groundnut, 4.60 q/ha in sesamum. The findings are in line with that reported by Kulkarni et al.(2018); Jyothi and Subbaiah (2019). The technology gap was 13.05 q/ha in kharif groundnut, 9.33 q/ha in rabi groundnut, 1.00 q/ha in sesamum. The findings are in line with that reported by Lakshmi et al. (2017). The technology gap and extension gap are presented in Fig. 1.

The yield gap was 23.16% in kharif groundnut, 35.90% in rabi groundnut, 44.23% in sesamum. The technology index was 26.10% in kharif groundnut, 18.66% in rabi groundnut, and 6.25% in sesamum. The findings are in line with that reported by Balai et al. (2013) and Raj et al. (2013).

The economics of the demonstrations indicated that in kharif groundnut, the cost of cultivation was ₹ 45,000/ha, with an average gross returns of ₹ 1,84,750/ha, accounting to average net return of ₹ 1,39,750/ha with a benefit cost ratio of 4.11:1. In the check plot, cost of cultivation was ₹ 51,000/ha, with an average gross returns of ₹ 1,50,000/ha, accounting to an average net return of ₹ 99,000/ha with a benefit cost ratio of 2.94:1 as presented in Table 4. Farmers practice plots incurred an additional cost of ₹ 6000/ha as compared to demonstration. As a result of the demonstrations an additional returns of ₹ 34,750/ha was recorded in demonstration plot. The effective gain noticed in demonstration was ₹ 28,750/ha with an incremental cost benefit ratio (ICBR) of 5.80.

In rabi groundnut, the cost of cultivation was ₹ 48,000/ha, with an average gross returns of ₹ 2,03,850/ha, accounting to the average net returns of ₹ 1,55,850/ha with a benefit cost ratio of 4.25:1. In the check plot, cost of cultivation was ₹ 52,500/ha, with an average gross returns of ₹ 1.50,000/ha, accounting to the average net returns of ₹ 97,500/ha with a benefit cost ratio of 2.86:1. Farmers practice incurred an additional cost of ₹ 4500/ha as compared to demonstration. As a result of the demonstrations an additional returns of ₹ 53,850/ha was recorded in demonstration plot. The effective gain noticed in demonstration was ₹ 49,350/ha with an incremental cost benefit ratio (ICBR) of 11.97.

In summer sesamum, the cost of cultivation was ₹ 20,000/ha, with an average gross returns of ₹ 90,000/ha, accounting to the average net return of ₹ 70,000/ha with a benefit cost ratio of 4.50:1. In the check plot, cost of cultivation was ₹ 20,000/ha, with an average gross returns of ₹ 62,400/ha, accounting to the average net returns of ₹ 42,400/ha with a benefit cost ratio of 3.12:1. As a result of the demonstrations, an additional returns of ₹ 27,600/ha was recorded in demonstration plot.

The demonstration was found to be superior in terms of yield, total returns and profits over the check in case of both groundnut and sesamum. In kharif groundnut, yield difference of 6.95q/ha was observed between demonstration and check plots. The difference in total returns observed was ₹ 34,750/ha and the profit recorded was ₹ 40,750/ha over check. The findings are in line with that reported by Patil et al. (2018), Gorfad et al. (2016). The calculated t values showed significant and positive difference between improved practice and farmers practice (Table 5).

In rabi groundnut, yield difference of 10.77 q/ha was observed between demonstration and check plots. The difference in total returns observed was ₹ 53,850/ha and the profit recorded was ₹ 58,350/ha over check. The calculated t values showed significant positive difference between improved practice and farmers practice.

In summer sesamum, yield difference of 4.60q/ha was observed between demonstration and check plots. The difference in total returns observed was ₹ 27,600/ha and the profit recorded was ₹ 27,600/ha over check. The calculated t values (Table 5) showed significant positive difference between improved practice and farmers practice.

Farmers of the district were not completely adopting the recommended practices in groundnut and sesame crops thereby realizing lower yields and lower monetary returns. The FLDs in cluster approach created a considerable impact on the farmers in terms of higher yields, returns and paving the way for doubling of farmers' income. Concerted efforts are required to disseminate the information on improved technologies to the farmers of the district through various extension programmes creating awareness through campaigns, communication through print, electronic and mobile media. Capacity building of the stakeholders through training programmes and popularizing the success stories of farmers, who had conducted cluster FLDs.

Table 1 Identified adoption gaps in groundnut and sesamum

Item	Groundnut			Sesamum		
	Improved Practice	Farmers Practice	Gap	Improved Practice	Farmers Practice	Gap
Variety	K-7 bold	TAG 24	Full gap	YLM 66	YLM 17	Full gap
Land preparation	Tractor drawn cultivator/Rotavator	Tractor drawn cultivator/Rotavator	No gap	Tractor drawn cultivator/Rotavator	Tractor drawn cultivator/Rotavator	No gap
Seed treatment	Carbendazim 50% WP @ 1 g/kg seed, imidacloprid 18.6 SL @ 2.0 ml/kg seed and liquid Rhizobium 10 ml /kg seed.	No seed treatment	Full gap	Carbendazim 50% WP @ 2.5 g/kg seed, imidacloprid 18.6 SL @ 3.0 ml/kg seed	No seed treatment	Full gap
Sowing time	June-July (kharif) October (Rabi)	June-July (kharif) October (Rabi)	No gap	January second fortnight	February	No gap
Seed rate	175 kg	175 kg	No gap	6-7 kg/ha	6- 7 kg/ha	No gap
Fertilizer management	20-50-50NPK and 500 kg gypsum kgha-1	30-46-30 kg ha-1	Partial gap	60-20-20 NPK kg ha-1	18-46-00 NP kgha-1	Partial gap
Weed Control	Pre-emergence herbicide Pendimethalin @ 1.0 kg a.i/ha and harrowing at 25-40 DAS	Manual weeding and Harrowing at 25-40 DAS	Partial gap	Pre-emergence herbicide Pendimethalin @ 1.0 kg a.i/ha and Manual weeding at 25-30 DAS (if necessary)	Manual weeding at 25-30 DAS	Partial gap
Irrigation	Irrigation at Critical stages	Irrigation at Critical stages	No gap	Irrigation at vegetative, flower bud and pod maturity	Irrigation at vegetative, flower bud and pod maturity	No gap
Plant protection	IPM practice for lepidopteran pests	IPM not practiced	Full gap	IPM practices for Sucking pests	IPM not practiced	Full gap
Harvesting	Manual harvesting	Manual harvesting	No gap	Manual harvesting and threshing	Manual harvesting and threshing	No gap

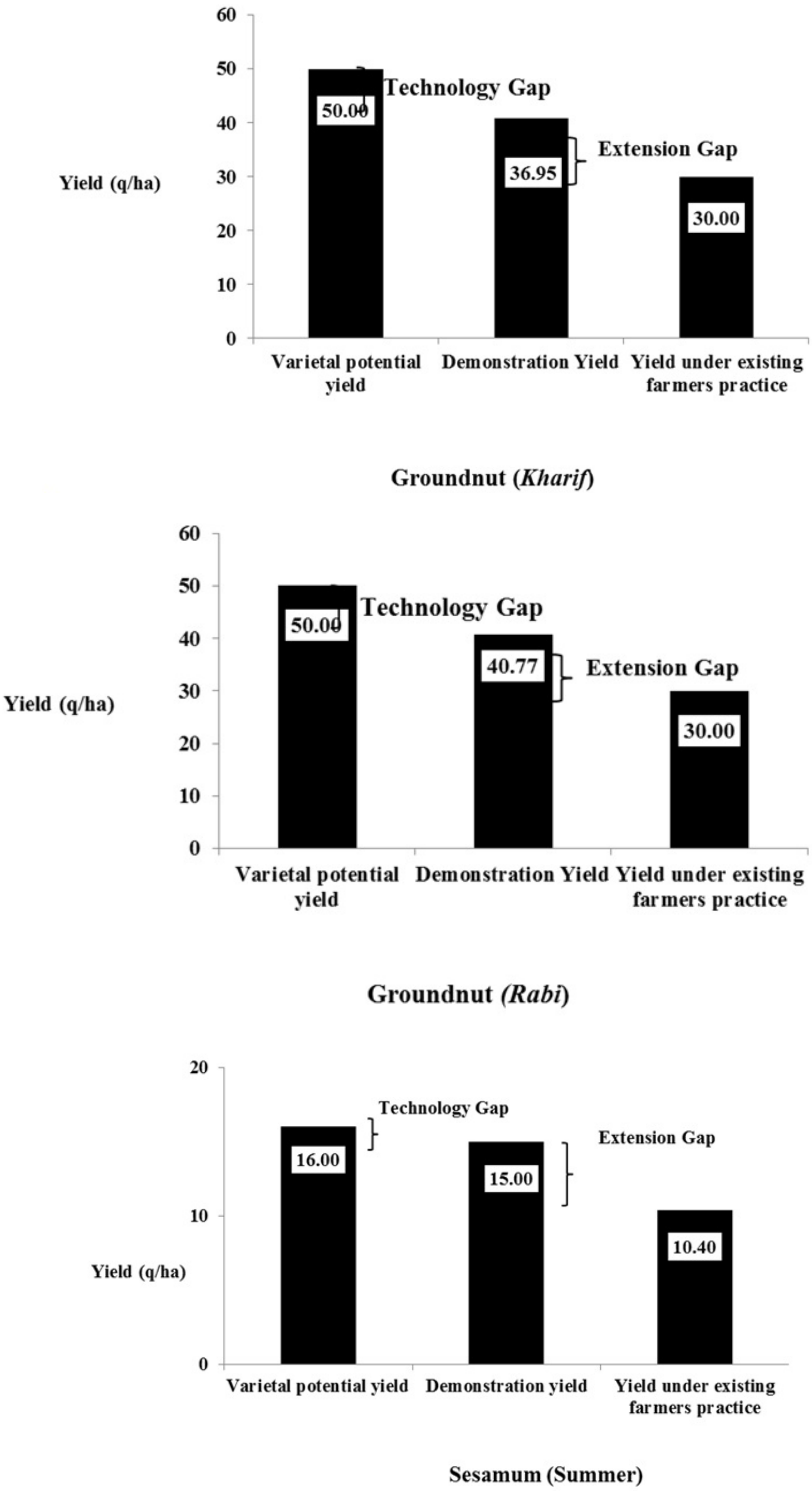

Fig. 1. Graphical representation of technology gap and extension gap

Table 2 Distribution of respondents based on adoption gaps

Category	Groundnut		Sesamum	
	Frequency	Percentage	Frequency	Percentage
Low (Mean – 0.5 SD)	20	50.00	20	50.00
Medium (Mean + 0.5 SD)	8	20.00	8	20.00
High (Mean + 0.5 SD)	12	30.00	12	30.00
	Mean = 1.8	SD = 0.88	Mean = 1.8	SD = 0.88

Table 3 Yield details of groundnut and sesamum

Crop/Season	No. of Farmers/ Demonstrations	Area (ha)	Yield (q/ha)				% increase in Yield
			Demonstration plot			Check variety	
			High	Low	Average		
Groundnut (Kharif)	40	40	41.75	36.97	36.95	30.00	23.17
Groundnut (Rabi)	40	40	41.63	39.63	40.77	30.00	35.90
Sesamum (Summer)	80	80	15.20	14.80	15.00	10.40	44.23

Table 4 Economic details of groundnut and sesamum

Crop/Season	Economics of Demonstration (₹/ha)				Economics of check (₹/ha)			
	Gross cost	Gross returns	Net returns	BC ratio	Gross cost	Gross returns	Net returns	BC ratio
Groundnut (Kharif)	45000	184750	139750	4.11	51000	150000	99000	2.94
Groundnut (Rabi)	48000	203850	155850	4.25	52500	150000	97500	2.86
Sesamum (Summer)	20000	90000	70000	4.50	20000	62400	42400	3.12

Table 5. Profit through improved management practices groundnut and sesamum by paired t test

Item	Improved Practice			Farmers Practice			Difference			t value		
	Groundnut (Kharif)	Groundnut (Rabi)	Sesamum (Summer)	Groundnut (Kharif)	Groundnut (Rabi)	Sesamum (Summer)	Groundnut (Kharif)	Groundnut (Rabi)	Sesamum (Summer)	Groundnut (Kharif)	Groundnut (Rabi)	Sesamum (Summer)
Yield (q/ha)	36.95	40.77	15.00	30.00	30.00	10.40	6.95	10.77	4.6	4.35*	5.14*	3.39*
Total return (₹/ha)	184750	203850	90000	150000	150000	62400	34750	53850	27600	3.68*	4.79*	2.96*
Profit (₹/ha)	139750	155850	70000	99000	97500	42400	40750	58350	27600	4.13*	2.65*	3.79*

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Genetic variability and divergence studies in sesame (*Sesamum indicum* L.)

BABITA KUMARI AND S R KUMHAR

Agricultural Research Station, Agriculture University Jodhpur, Mandor, Jodhpur-342 304, Rajasthan

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ABSTRACT

Genetic variability and divergence were studied in 40 genotypes/varieties of sesame for eleven yield and yield related traits. Analysis of variance exhibited significant differences for all the characters suggesting the presence of large amount of inherent genetic variability among the genotypes studied. The maximum magnitudes of phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) were observed for number of primary branches per plant, number of capsules per plant and capsule bearing length (cm). Estimates of heritability was high for number of primary branches per plant, days to 50% flowering and seed yield, days to maturity, and high heritability coupled with high genetic advance as 5% of mean was observed for number of primary branches per plant and seed yield per plant suggesting additive gene action for expression of these characters. The hierarchical cluster analysis indicated the presence of considerable genetic divergence among the genotypes/varieties. The genotypes were grouped into seven clusters using Ward's minimum variance method. The inter-cluster Euclidean2 distance was maximum between cluster-III and VII (68.33) followed by cluster-IV and VII (61.40) and cluster-II and VII (59.59) which indicated that the genotypes included in these clusters could give high heterotic response and thus better segregants. The maximum cluster means were revealed by cluster-II for number of capsules per plant, capsule bearing length and seed yield per plant followed by cluster VII for number of primary branches per plant and 1000 seed weight, and cluster-VI for number of seeds per capsule. Based on this observation, it could be concluded that genotypes carefully chosen from clusters II, VI and VII, would offer a better scope of improvement of sesame through recombination breeding.

Keywords: Sesame, genetic variability, genetic advance, heritability

Sesame (Sesamum indicum L.), is one of the most important oilseed crops in warm temperate to tropical areas from about 40° N latitude to 40° S latitude. It is generally self-pollinated crop, but cross-pollination may occur and range from 5 to over 50 per cent, (Pathirana, 1994). Sesame is often referred to as the "Queen of Oilseeds" and its seeds contain 45-60% oil and 18-25% protein. Like flax, sesame is a valuable oilseed crop with immense therapeutic uses and its oil has the highest antioxidant content and predominantly contains oleic acid (43%), linoleic acid (35%), palmitic acid (11%), and thus a balance of both monounsaturated fatty acids and polyunsaturated fatty acids in general (Hansen, 2011).

In any crop improvement programme, direct selection for yield as such could be misleading because effective selection depends on the information about genetic variability and association of yield component traits with seed yield. The logical way to begin any breeding programme is to evaluate the existing genetic variability, because the assessment of variability forms the basis of any crop improvement programme. It is necessary to study variability in respect of quantitative traits and genetic parameters, such as genotypic and phenotypic variances, heritability (broad sense) and genetic advance to devise appropriate selection indices and exercise selection. When the required genetic variability is present in a genetic stock, selection for seed yield would be efficient. Therefore, information on genetic divergence in sesame will be helpful in identifying diverse genotypes which can be recombined together for creating new variability and develop improved genotypes.

The experiment in present study comprised of 40 genotypes/varieties of sesame. The experimental material was sown by adopting randomized block design with three replications during kharif season 2018 under rainfed conditions at experimental field of Agricultural Research Station, Agriculture University, Mandor, Jodhpur, Rajasthan. During kharif 2018 the rainfall was very erratic and scanty; therefore, two life-saving irrigations were given to the crop. Each genotype was grown in 4.0 m length of two rows with spacing of 30 cm between rows and 15 cm from plant to plant. The crop was supplied with 250 kg/ha gypsum 20 days before growing time and 25 kg/ha phosphorus and 40 kg/ha nitrogen was given at the time of sowing. Observations were recorded on days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of capsules per plant, number of seeds per capsule, capsule bearing length (cm), 1000 seed weight (g), harvest index (%), oil content (%) and seed yield per plant (g). The analysis of variance was done as per Panse and Sukhatme (1978), genetic variability parameters as per Johnson et al. 1955, Heritability as per Warner (1952) and clustering was performed by procedure of Ward's (1963) minimum variance method using Windostat Software, Hyderabad.

Corresponding author's E-mail: srkumhar@gmail.com

The analysis of variance for the characters under study showed highly significant differences among the genotypes for all the eleven traits (data not presented) indicating the presence of considerable genetic variability in the experimental material. The magnitudes of phenotypic coefficients of variation (PCV) were greater than genotypic coefficients of variation (GCV) for all the characters with narrow difference indicating lesser environmental influence on trait expression (Table 1). The value of GCV and PCV was maximum for number of primary branches per plant followed by seed yield per plant and showed the presence of higher variability for these traits. These results are in confirmation with those of Abhijatha et al. (2017) and Singh et al. (2018). High value for phenotypic coefficient of variance was obtained for number of capsules per plant and similar results were also reported by Abhijatha et al. (2017), Patil and Lokesha (2018), Patil et al. (2018) and Singh et al. (2018). Moderate GCV and PCV (10-20%) were obtained for the character capsule bearing length (cm) [Teklu et al. (2017)]. The trait, number of capsules per plant showed moderate GCV and it was also confirmed by Singh et al. (2018). Moderate value of PCV for plant height, number of seeds per capsule and 1000 seed weight is in line with the observations made by Teklu et al. (2017) and Patil et al. (2018). Low value of GCV and PCV was showed by days to 50% flowering, days to maturity and oil content (%) and similar results have been reported by Sudhakar et al. (2007) and Abhijatha et al. (2017).

Estimations of heritability, in broad sense, were high (>80%) for days to 50% flowering, days to maturity, number of primary branches per plant and seed yield per plant (g) indicating that these traits might be controlled by additive gene action and therefore, direct selection would be effective for improving these traits. Similar results were also reported by Abhijatha et al. (2017). The value of heritability was moderate (60-80%) for number of capsules per plant and low (<60%) for plant height (cm), capsule bearing length (cm), number of seeds per plant, 1000 seed weight (g) and harvest index (%). In such type of studies, the heritability and genetic advance are two complementary ideas. Thus, heritability values can be used to predict the genetic advance through selection for predicting the utility and value of selection. High magnitudes of heritability coupled with high genetic advance as 5% of mean were observed for the traits like number of primary branches per plant and seed yield per plant (g). Thus, it can be inferred that these traits were controlled by additive gene action and could be considered as a breeding criterion for improving the seed yield in sesame. The trait, number of capsules per plant showed moderate heritability coupled with high genetic advance whereas; capsule bearing length, number of seeds per capsule and 1000 seed weight had moderate heritability with moderate per cent genetic advance. Days to 50% flowering showed high heritability coupled with moderate genetic advance as per cent of mean and days to maturity enumerated high heritability and low genetic advance as per cent of mean. In this condition selection will be more effective for these characters in seed yield improvement. However, low heritability and low genetic gain was observed for plant height (cm), harvest index (%) and oil content (%), therefore, selection for these characters may not be much effective.

A hierarchical cluster analysis of Ward's minimum variance method produced a dendrogram showing successive fusion of individuals which clearly partitioned the genotypes into seven clusters (Table 2). The genotypes within each cluster were closer to each other than the genotypes grouped into different clusters. Maximum number of genotypes were found in cluster-III and V (9) followed by eight in cluster I, seven in cluster II, three in cluster-IV and VI, one in cluster-VII (Table 2). Average intra and inter-cluster Euclidean2 distances are represented in Table 3. Maximum intra-cluster distance was observed in cluster-IV (23.40) followed by cluster-II (13.77), cluster-III (13.06) and cluster-V (12.26) indicating wide genetic variability within the genotypes of these four clusters (Table 3).

The highest inter-cluster distance was observed between cluster-III and VII (68.33) followed by cluster-IV and VII (61.40) and cluster-II and VII (59.59), suggesting wide diversity between genotypes of these clusters. Therefore, genotype belonging to these clusters may be used in hybridization programme for improvement of sesame and gave better segregants. The least inter-cluster distance was observed between clusters-III and V (17.73) indicating close relationship between the genotypes of these two clusters. The diversity was also supported by the appreciable amount of variation among the cluster means for different characters (Table 3). The highest cluster mean revealed by cluster-II for number of capsules per plant, capsule bearing length and seed yield per plant, cluster-VII for number of primary branches per plant and 1000 seed weight, cluster-VI for number of seeds per capsule while cluster-III was having maximum value for oil content and lowest value for days to 50% flowering and days to maturity, similarly cluster-IV was maximum for harvest index and lowest for plant height (Table 4). These results showed that genotypes in different clusters were superior for different characters and depending on the trait of interest of the breeding programme they could be selected.

Amongst the characters, number of primary branches per plant contributed maximum towards genetic divergence (28.97%) followed by days 50% flowering (23.72%) and seed yield per plant (21.15%), while character harvest index (0.38%) contributed least to genetic divergence (Table 4). These results are in conformity with those reported by Anuradha and Reddy, 2005, Kumhar et al. 2013, Narayanan and Murugan, 2013, Tripathi et al. 2014, Patil et al. 2018.

Since varieties with narrow genetic base are more vulnerable to diseases and adverse climatic conditions, availability of the diverse genotypes for hybridization programme becomes more important. In the present study the maximum inter-cluster distance observed between cluster cluster-III and VII, cluster IV and VII, and cluster II and VII and crosses among genotype/varieties of these clusters viz RMT-293, RMT-251, EC-357309-1, GT-10, RMT-244, IC-204531(A), IC-203936, IC-203937 (Table 2) might result in better transgressive segregants. Since, number of primary branches per plant, days to 50% flowering and seed yield per plant contributed maximum towards the divergence, direct selection for these traits might help in crop improvement.

Table 1 Estimates genetic parameters estimated for eleven traits in sesame

Characters	Mean ± S.Em	Range	Coefficient of variance		Heritability	GA	GA as 5% of mean
			GCV(%)	PCV (%)			
Days to 50% flowering	51.20 ± 0.71	44.67-60.33	6.53	6.96	88.00	6.46	12.62
Days to maturity	86.59 ± 0.61	83.67-94	2.55	2.83	81.29	4.11	4.74
Plant height (cm)	91.47 ± 4.39	76.13-105.04	6.75	10.71	39.69	8.01	8.75
No. of primary branches/ plant	3.59 ± 0.24	1.73-8.26	34.42	36.25	90.15	2.42	67.32
Capsule bearing length (cm)	44.72 ± 2.48	30.8-53.37	10.11	13.95	52.54	6.75	15.10
No. of seeds/capsule	51.31 ± 2.42	38.87-62.5	8.42	11.73	51.58	6.39	12.46
No. of capsules/ plant	40.31 ± 3.02	28.93-61.37	18.86	22.88	67.94	12.91	32.03
1000 seed weight (g)	3.01 ± 0.13	2.53-3.83	7.95	10.80	54.16	0.36	12.05
Seed yield/ plant (g)	3.38 ± 0.28	1.69-6.11	31.71	34.70	83.48	2.02	59.68
Harvest index (%)	27.32 ± 2.35	23.15-35.13	8.49	17.15	24.49	2.36	8.65
Oil content (%)	40.25±0.82	32.32-42.91	4.09	5.39	57.48	2.57	6.38

GCV= Genetic Coefficient of Variance, P= Phenotypic Coefficient of Variance, GA= Genetics Advance

Table 2 Distribution of sesame genotypes/ varieties in seven clusters

Clusters	No. of genotypes/ varieties	Name of genotypes/varieties
Cluster-I	8	RT-203, EC-370867, RT-354, RT-288, RT-194, EC- 357315, EC-362360, RT-329
Cluster-II	7	RMT-293, RMT-251, EC-357309-1, GT-10, RMT-244, IC-204531, IC-203936
Cluster-III	9	RT-204, IC-203984, RT-351, RMT-239, IC-203939, RMT-258, EC-370400, EC-357304, EC-370800
Cluster-IV	3	EC-370773, IC-203985, RT-54
Cluster-V	9	RT-294, IC-203926, IC-357028, TKG-22, RMT-196, EC-270920, IC-203897, EC-351816, EC-357309
Cluster-VI	3	IC-203983, IC-203896, IC-204528
Cluster-VII	1	IC-203937

Pedigree/ Source- All RT and RMT series genotypes are developed at ARS, Mandor, Jodhpur, GT-10 was procured from ARS, Amreli, Gujarat and EC and IC were procured from PC Unit (sesame and Niger), ICAR, JNKVV Campus Jabalpur.

Table 3 Average intra-cluster (diagonal values) and inter cluster values among seven clusters in sesame

Cluster	Cluster-I	Cluster-II	Cluster-III	Cluster-IV	Cluster-V	Cluster-VI	Cluster-VII
Cluster-I	11.57	18.02	18.32	28.59	17.90	22.83	58.94
Cluster-II		13.77	25.92	30.83	21.66	19.52	59.59
Cluster-III			13.06	28.65	17.73	28.10	68.33
Cluster-IV				23.40	24.99	37.08	61.40
Cluster-V					12.26	18.23	40.14
Cluster-VI						7.58	39.52
Cluster-VII							0.00

Table 4 Cluster means in different clusters and percent contribution for different characters in sesame

Cluster	Days to50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/ plant	No. of capsules/ plant	Capsule bearing length (cm)	No. of seeds/ capsule	1000 seed weight (g)	Seed yield/ plant (g)	Harvest index (%)	Oil content (%)
I	49.42	85.67	99.29	3.37	38.94	45.99	51.16	3.27	3.84	28.48	40.56
II	50.33	86.33	91.70	4.59	52.22	47.91	49.80	2.94	4.59	29.49	40.02
III	48.33	84.70	88.56	2.69	35.08	45.89	52.33	2.91	2.37	25.47	41.42
IV	52.22	85.78	81.46	2.56	32.19	41.99	52.98	2.87	3.60	32.58	36.91
V	53.33	87.85	89.58	3.42	38.47	41.61	48.89	2.99	2.82	25.85	40.14
VI	56.11	89.89	94.64	4.52	47.52	47.01	57.27	2.88	4.30	24.02	40.79
VII	60.33	94.00	91.11	8.26	34.38	30.80	52.80	3.28	1.87	26.87	38.15
Contribution to diversity (%)	23.72	5.26	2.05	28.97	2.18	2.44	3.72	3.59	21.15	0.38	6.54

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Morpho-physiological and yield traits of sesame (*Sesame indicum* L.) varieties under rainfed conditions

K N RAVITEJ, P RATNAKUMAR*, B B PANDEY, S NARENDER REDDY, V GOURI SHANKAR AND D PADMAJA

Department of Crop Physiology, College of Agriculture, PJTSAU, Hyderabad-500 030, Telangana

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ABSTRACT

A field experiment was conducted during kharif, 2018 to evaluate the performance of 10 sesame varieties viz., RT-346, RT-351, RT-127, GT-10, TKG-22, SWETHA, JCSDT-26, DS-1, YLM-66 and KMS-4-322 for morphological, physiological and yield traits under rainfed conditions in randomized block design with three replications. Results indicated that the varieties significantly differed for morphological parameters viz, plant height (PH), number of branches (NB), leaf area (LA), days to 50% flowering, days to maturity, and for physiological parameters viz., SPAD chlorophyll meter reading (SCMR), leaf temperature (LT), relative water content (RWC) and for yield parameters viz., number of capsules per plant, single capsule dry weight, number of unfilled capsules per plant, 1000 seed weight, seed yield, total dry matter and harvest index (HI).Variety JCSDT-26 recorded high seed yield, number of capsules per plant, single capsule dry weight along with maximum SCMR, RWC, minimum LT indicating the role of these physiological traits for better performance of this variety under rainfed conditions; followed by Swetha, RT-127, GT-10 and YLM-66. Based on the performance of the variety JCSDT-26, it could be concluded that the variety could be suitable for cultivation under rainfed conditions.

Keywords: Morphological traits, Physiological traits, Yield traits, Rainfed conditions, Sesame

About 80% of the world and 60% of the Indian Agriculture is rain-dependent, diverse, complex, under-invested, risky, distress prone and vulnerable (NRAA reports, 2018). Uncertainties and seasonal migrations have further compounded due to high frequency of extreme weather events like droughts due to global warming (IPCC 2018). Most of the oilseeds are cultivated under rainfed conditions and their yields oscillate depending on rainfall and other weather conditions. India ranks first, both in area and production of sesame in the world. The annual area in India is about 2-5 M ha (45 % of the world area) and total production is nearly 52 thousand tonnes that fluctuates with variety, local weather conditions and nutrient inputs.

Sesame (Sesame indicum L.) the 'queen of oilseeds', known for its high oil content and quality (Johnson et al., 1979) belongs to Pedaliaceae family. It is widely grown in tropical and subtropical areas and documented as the most ancient oil crop providing humans with essential daily energy. Vegetable oil consumption is expected to reach almost 200 billion kilograms by 2030 (Troncoso-Ponce et al., 2011), and which will further increase the demand for oil-rich crops. Compared to other edible oil crops such as soybean, rapeseed, groundnut and olive, sesame has innately higher oil content (approximately 54% of dry seed weight) (Wei et al., 2013) and it is also used in therapeutic medicine. Like many other crop species, sesame is sensitive to drought during its vegetative stage (Boureima et al., 2012).

*Corresponding author's E-mail: pratnakumar@gmail.com; ratna.pasala@icar.gov.in

Rainfed agriculture constitutes 80% of global agriculture and plays a critical role in achieving global food security. However growing world population, water scarcity and climate change threaten rainfed farming through increased vulnerability to abiotic stresses. Rainfed area experience 3 to 4 years of drought in every 10 year period. Of these two to three are moderate and one or two are with severe stress intensity (Srinivasrao et al., 2013). Generally, sesame is cultivated in rainfed areas with minimum inputs, often exposed to water stress resulting in low yields. Therefore, it is essential to study the morphological, physiological yield traits under rainfed conditions to identify the suitable variety that adopt to rainfed situation of sesame cultivated states of India.

An experiment was carried out at ICAR-IIOR Research Farm at Narkhoda, Hyderabad which is located at an altitude of 542 metres above MSL with a geographical bearing of 17°15'16" N latitude and 78°18'30" E longitude. The experiment was laid out in a Randomized Block Design (RBD) with three replications during Kharif 2018. Plot size was 12 Square meter and the row spacing of 45 cm and intra row spacing of 15 cm. Sowing was done by dibbling and applied recommended fertilizer dose (40 kg N + 20 kg P2O5 + 20 kg K2O/ha) in two spilts and other package of practices were followed to raise a healthy crop. Prophylactic measures were adopted against pests and diseases. Total rainfall received during the experimental period and its distribution is presented in Figure1.

A set of 10 sesame varieties, including national and local check were selected for the study. Varietal seed colour, pedigree, year of release and state are presented in Table-1. Five random plants of each variety were selected in each replication to record data on different traits viz., plant height (cm), number of branches per plant, leaf area (cm2), days to 50% flowering and days to maturity. Total leaf area was measured using bench-top leaf area meter (LICOR-3100C), after taking all the leaves from the stem. Days to 50 per cent flowering was recorded after 50 percent of the plants flowered in each plot. Physiological parameters, SPAD chlorophyll meter readings (SCMR measured using SPAD-502 Plus, Konica Minolta Inc.), and leaf temperature (LT with IR thermal gun AGRI-THERM-6210L; Everest inter-science Inc.) were measured in fully matured leaf from the stem apex. Measurements were made during sunny day between 10 and 13 hrs (IST) in 10 plants of each replication. Relative water content (RWC) was recorded at peak plant growth period i.e., 45 days after sowing. Yield and yield attributes were also recorded after harvest of the crop. The mean values were considered for statistical analysis using SAS (SPS.9.0)

Quantification of sesame varietal responses under deficit rainfed conditions are essential to understand the morpho-physiological traits contributing to the seed yield, and to identify the variety with maximum yield having better adaptability under rainfed situations. The morphological traits such as plant height, no of branches, days to 50% flowering, LA, days to maturity varied significantly among the varieties tested (Table 2). The plant height ranged from 62.2 to 97.3 cm and recorded maximum in Swetha and minimum in RT-346. Number of branches ranged from 3 to 5 among varieties and maximum was in Swetha, JCSDT-26 and minimum in RT-346, RT-351 and RT-127. LA of different sesame varieties ranged from 74.8 to 482.7cm2. The varieties Swetha, JCSDT-26 and KMS-4-322 had greater LA than other varieties tested. Similarly, sesame varietal variations have been documented by Channabasavanna and Setty (1992). These differences could be due to the genetic makeup of the varieties or response to the environmental factors (Chandrasekhar et al., 2001).

The variety JCSDT-26 and Swetha took maximum days for 50% flowering i.e., 41 days; while DS-1, YLM-66 and RT-346 were 34 days; RT-127 was 33 days and RT-351 was 32 days. Days to 50% flowering had positive correlation with seed yield of sesame. Similar findings were also documented in sesame cultivars (Rao et al., 1985; Tomar et al.,1992). There were significant differences for days to maturity among the varieties tested and Swetha and JCSDT-26 recorded late maturity while RT-346, RT-351 and RT-127 recorded early maturity under rainfed conditions. Days to maturity was positively correlated with seed yield under rainfed conditions in sesame varieties tested (Table 5).

Physiologically adapted/resistant traits such as plant tissue water content, cooler canopy for more gas exchange per unit of water loss and with more chlorophyll for carbon fixation under rainfed/ deficit irrigated conditions are crucial for plant yield/survive (Minhas et al., 2017). SPAD of sesame varieties varied significantly and ranged between 47.5 to 53.4 and JCSDT-26 recorded maximum SPAD. Reduction or loss of chlorophyll in some varieties (Table 3) was due to severe water stress that further led to pigment photo-oxidation, loss of chloroplast membranes (Anjum et al.,2011; Sarkar et al., 2016). Leaf temperature (LT), a proxy of canopy temperature varied significantly among the varieties and the values ranged from 27.7 to 33.8oC. Minimum LT was recorded in JSCDT-26 followed by YLM-66 and RT-346 while the maximum LT was recorded in KMS-4-322. The variety JCSDT-26 expressed lesser LT, indicating the well maintained water uptake in terms of transpiration. RWC ranged between 68.9 to 76.4 % and JCSDT-26 expressed maximum RWC at 76.4% followed Swetha at 75.3% and DS-1 at 73.9% while the minimum was found in RT-127 68.9% (Table 3). Since all the varieties were grown under rainfed conditions, SPAD (r2:0.84) and RWC (r2:0.72) was positively correlated with seed yield (Table 5). Plant water use is an important trait under rainfed and drought conditions (Ratnakumar et al., 2009), the variety that can hold/use maximum water content, that could further translate into seed yield is considered to be the best under rainfed water deficit situations. Like in groundnut (Ratnakumar and Vadez 2012), the variety JCSDT-26 showed strong correlation between RWC and SPAD.

Yield attributes such as number of capsules per plant, varied significantly among the sesame varieties evaluated (Table 4) and it ranged from 33 to 84. Maximum number of capsules per plant was recorded in JCSDT-26, while the lowest was in RT-127. The increase in number of capsules in JCSDT-26 and Swetha may be due to their maximum plant height which could be attributed to more number of nodes. All varieties expressed significant difference for seed yield under rainfed conditions. Seed yield ranged from 7 to 4 g per plant and JCSDT-26 was recorded high seed yield followed by Swetha and DS-1 under rainfed conditions (Table 4). Minimum seed yield was recorded in RT-351 followed by RT-346 and RT-127. It was noticed that number of unfilled capsules in TKG-22 were quite high, further leading to the reduction of seed yield compared to other varieties.

The capsule weight ranged from 0.34 to 0.24 g per plant, with maximum weight recorded in JCSDT-26 (0.34 g), Swetha and GT-10 (0.33 g) while minimum capsule dry weight was recorded RT-351 (0.27 g), YLM-66 (0.26 g) and RT-127 (0.24 g). The variety with maximum capsule number and weight can contribute more seed per plant and thus a variety with more capsules could be a better performer under rainfed conditions. Similar results were confirmed in sesame by Akter et al. (2016) and Sumathi et al. (2010). Total dry matter (TDM) accumulation was recorded more in

JCSDT-26 and Swetha, whereas the minimum was recorded in TKG-22 followed by RT-346 and YLM-66. There was significant difference between the varieties for total dry matter and in the present study the reduction of total dry matter in some varieties may be due to reduction in rate of photosynthesis under deficit rainfall conditions. Maximum total dry matter in some varieties was attributed due to increase in the SPAD values that leads to higher rates of photosynthesis (Akter et al., 2016). The difference in dry matter production among the varieties may also be due to the manipulation of source and sink (Chongdar et al., 2015; Howlader et al., 2018).

The traits association/contribution to seed yield under rainfed situation is an important aspect especially in oilseeds cultivated in semi-arid tropics. Most of the traits i.e., LA, number of branches, days to maturity, SPAD, RWC were positively correlated with seed yield (Table 5). Traits like 1000 seed weight, number of capsules per plant also had positive correlation as reported in other studies in sesame (Aristya and Taryono, 2016; Raghuwanshi et al., 1994).

Test weight /1000 seed weight significantly varied from 2.4 to 3.5g among the varieties tested. The maximum test weight was recorded in JCSDT-26 followed by SWETHA and least in GT-10 followed by YLM-66. Test weight was positively correlated with the seed yield like in other studies (Babu and Reddy, 2004; Chongdur et al., 2015). There was significant difference among the varieties for harvest index (HI). Maximum HI recorded in varieties is known to be due to higher number of branches and better retention of capsules in sesame (Saha and Bhargava 1980).

Based on results of the present study, the variety JCSDT-26 recorded high values for maximum traits such as plant height, LA, number of branches, number of capsule, RWC, SPAD, lesser LT, total dry weight, test weight and seed yield. These traits showed significant positive association with seed yield under rainfed conditions.

Table 1 Seed colour, pedigree, released year and state details of selected sesame varieties

Variety	Seed colour	Pedigree	Year of release	Released state
RT-346	White	RT 127 X HT 24	2009	Rajasthan
RT-351	White	NIC 8409 X T127	2011	Rajasthan
RT-127	White	Si3500 X Patan-64	2001	Rajasthan
GT-10	Black	TNAU17 selection	2005	Gujarat
TKG-22	White	HT6 X JLT-3	1995	M.P
SWETHA	White	E 8 X IS 114	1999	Telangana
JCSDT-26 *	White	Local selection	--	Telangana
DS-1	White	Local selection	--	Karnataka
YLM-66	Brown	PS201 X YLM-17	--	A.P
KMS-4-322	Brown	Improved landrace	---	Jharkhand

* JCSDT-26 variety was not yet released.

Table 2 Morphological parameters viz, plant height, leaf area, days to 50% flowering and days to maturity of the sesame varieties under rainfed conditions

Varieties	Plant height (cm)	Number of branches	Leaf area (cm2)	Days to 50% flowering	Days to maturity
RT-346	62.2	3.73	81.7	34.	84
RT-351	65.0	3.66	88.9	33	83
RT-127	67.6	3.47	74.8	33	83
GT-10	84.8	4.06	130.0	35	89
TKG-22	72.4	3.73	102.5	36	87
Swetha	97.2	4.66	482.7	41	106
JCSDT-26	92.7	4.53	360.4	41	106
DS-1	78.6	4.13	217.5	40	95
YLM-66	72.7	3.7	287.9	390	94
KMS-4-322	70.8	4.06	296.9	38	99
Mean	76.4	3.98	212.3	37	93
S.E.	1.43	0.13	4.03	1.12	0.82
CD (p=0.05)	3.01	0.29	8.46	2.36	1.74

Table 3 SCMR, leaf temperatures (LT) and relative water content (RWC) of sesame varieties under rainfed conditions

Varieties	SCMR	LT (°C)	RWC (%)
RT-346	49.26	27.71	73.40
RT-351	49.42	32.53	73.01
RT-127	48.21	29.00	68.95
GT-10	47.55	28.77	72.76
TKG-22	50.42	30.19	69.69
Swetha	53.30	28.72	75.34
JCSDT-26	53.48	27.83	76.40
DS-1	52.20	31.30	73.97
YLM-66	50.72	28.61	71.04
KMS-4-322	51.22	33.87	69.95
Mean	50.57	29.85	72.35
SE	0.78	0.53	1.86
CD (p=0.05)	1.66	1.11	3.91

Table 4 Yield and yield attributes of sesame varieties under rainfed conditions

Varieties	Total Number of capsules/plant	Single capsule dry weight (g)	1000 seed weight (g)	Seed yield (g/plant)	Total plant drymatter (g/plant)	Harvest index (%)
RT-346	40.77	0.28	2.88	5.10	24.8	20.54
RT-351	43.33	0.27	3.28	4.72	29.9	15.58
RT-127	32.55	0.24	3.17	4.52	27.9	16.20
GT-10	44.22	0.32	2.78	5.25	32.5	16.14
TKG-22	75.33	0.31	2.49	5.47	27.3	20.28
Swetha	79.89	0.33	3.39	6.21	32.0	19.42
JCSDT-26	84.43	0.34	3.52	6.58	34.2	19.25
DS-1	56.78	0.31	3.21	6.06	31.9	19.00
YLM-66	53.77	0.26	2.56	5.80	24.5	23.72
KMS-4-322	52.00	0.27	2.95	4.75	26.3	18.06
Mean	56.32	0.29	3.02	5.44	29.1	18.82
SE	1.91	0.01	0.08	0.02	0.02	0.60
CD(p=0.05)	4.01	0.02	0.18	0.01	0.16	1.29

Table 5 Correlations between morpho-physiological traits and yield of sesame varieties under rainfed conditions

	Seed yield	Plant height	No. of branches	LA	Days to 50% flowering	Days to maturity	SPAD	Leaf temp.	RWC	TDM	HI
Seed yield	1.000										
Plant height	0.780**	1.000									
No. of branches	0.925**	0.909**	1.000								
LA	0.806**	0.773**	0.851**	1.000							
Days to 50% flowering	0.870**	0.797**	0.839**	0.908**	1.000						
Days to maturity	0.905**	0.825**	0.916**	0.956**	0.943**	1.000					
SPAD	0.854**	0.614	0.768**	0.839**	0.882**	0.874**	1.000				
Leaf temp.	0.053	-0.354	-0.165	-0.129	-0.171	-0.082	0.025	1.000			
RWC	0.728*	0.632	0.746*	0.501	0.504	0.546	0.543	0.325	1.000		
TDM	0.696*	0.758*	0.739*	0.417	0.449	0.571	0.398	0.101	0.592	1.000	
HI	0.303	-0.037	0.154	0.429	0.470	0.343	0.489	0.096	0.126	0.470	1.000

* Significant at 5% level, ** Significant at 1% level

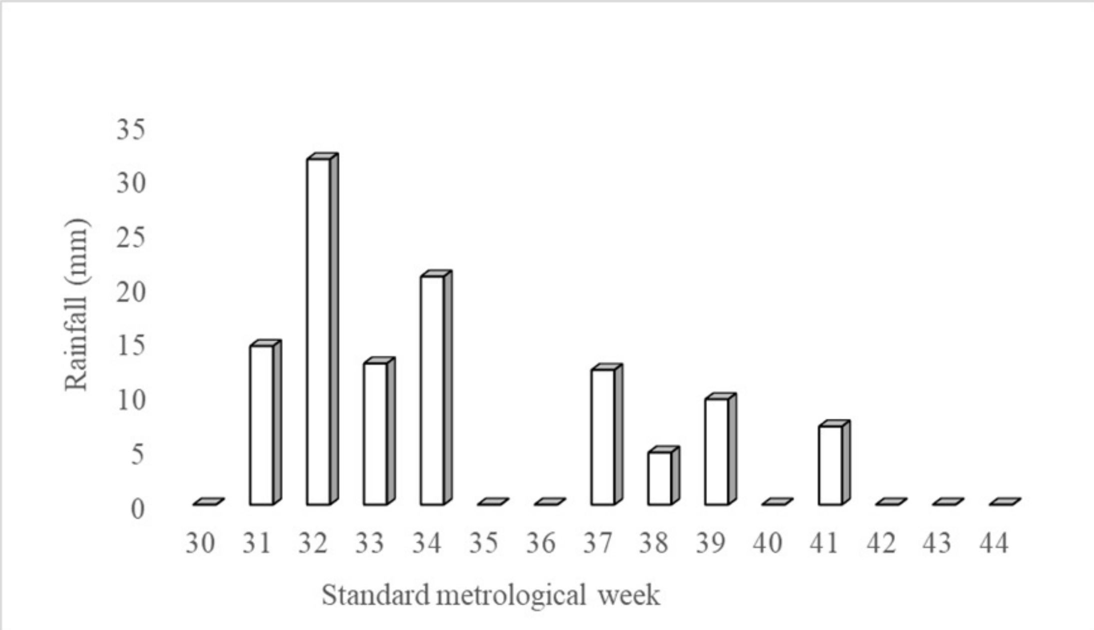

Fig.1. Weekly rainfall (mm) during crop growth period

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Identification of sources of resistance against Aphid, *Uroleucon compositae* (Theobald) in safflower

PANATHULA CHAITHANYA, P S SRINIVAS* AND A K SAXENA

ICAR-Indian Institute of Oilseeds Research, Hyderabad-500 030, Telangana

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ABSTRACT

Safflower (Carthamus tinctorius L.) is one of the most important traditional rabi oilseed crops grown in India. Safflower aphid, Uroleucon compositae(Theobald) is the key pest which causes yield losses to the extent of 30 to 78 per cent if not managed properly. Use of resistant varieties is one of the important components of IPM in safflower as the crop is mainly grown under resources poor conditions. The experiments were conducted during rabi, 2018-2019 at ICRISAT Farm, ICAR- IIOR, Hyderabad to evaluate 50 safflower germplasm accessions and 20 varieties for their reaction to aphids under artificial infestation. Test entries were infested with aphids artificially by transferring infested plants from an infester block raised separately. The reaction was recorded and categorized based on Aphid Infestation Index (AII) on 1.0 to 5.0 scale. Ten germplasm accessions, viz. GMU-671, GMU-599, GMU-3256, GMU-5133, GMU-5848, GMU-7868, GMU-7869, GMU-7870, GMU-7885, GMU-7917 were found moderately resistant to aphids with an average AII ranging from 2.3- 3.0. Out of 21 varieties evaluated, one variety, Girna was found resistant with an average AII of 2.0. Seven varieties viz. SSF-748, Bhima, A-1, SSF-708, PBNS-12, SSF-733 and Manjira were found moderately resistant to aphids with an average AII ranging from 2.3 to 3.0.

Keywords: Aphid, Plant resistance, Safflower, Screening, *Uroleucon compositae*

Safflower (Carthamus tinctorius L.: Asteraceae) is an important oilseed crop, grown in India since ages. This is cultivated on residual soil moisture in rabi season. Safflower is cultivated in India in Maharashtra, Northern Karnataka, Telangana, Madhya Pradesh, Gujarat and parts of Andhra Pradesh under different cropping systems. India's total production of safflower is 1.22 MT from an area of 1.56 lakh ha with a productivity of 782 kg per ha (Mukta et al., 2017). Aphid, Uroleucon compositae (Theobald) is considered as a major pest. A yield loss up to 78.5% was recorded on susceptible variety, SSF-658 whereas 48.5% was observed on moderately resistant variety, A-1 when proper control measures were not taken (Anonymous, 2015). Both nymphs and adults suck the sap from shoot and young leaves, due to which the plant growth is stunted. In case of severe attack of the aphid, the plants start showing yellowing and drying, resulting in premature death of plants. In addition, aphids also excrete honeydew, which falls on the upper surface of below leaves on which sooty mold develops hindering the photosynthetic activity (Balikai, 2000). Mostly, safflower crop is grown by small and marginal farmers with low inputs and may not receive any plant protection measures (Hanumantharaya et al., 2007) to minimize production cost. This often results in significant yield loss. Many authors have studied the reaction of safflower to aphids under natural infestation (Vijay Singh, 2008; Dayalu Patil, 2008; Kamal Anand, 2009; Rajput et al., 2013; Guljar and Rajesh, 2016). Few safflower accessions were reported for their reaction under artificial release of aphids (Srinivas and Mukta, 2015; Anonymous, 2015; Anonymous, 2016; Anonymous, 2017; Mukta et al., 2017).

Growing resistant cultivars of safflower offers a better alternative method that reduces the cost of plant protection and also safer to environment. Not many aphid resistant sources are identified from large collection of safflower germplasm available. Therefore, it is very important to identify aphid resistant sources of safflower germplasm, which will be used in breeding programme to develop resistant varieties. Twenty four safflower varieties have been developed and released so far in safflower. But their reaction to aphid under field conditions is not known. Therefore, the present investigation was undertaken to identify resistance sources from safflower germplasm accessions and released cultivars.

The present study was carried out at ICAR- IIOR Farm, ICRISAT (17.5300 N latitude and 78.2700 E Longitude) during rabI season of 2018-2019. The experiment was carried out in randomized block design (RBD) with two replications. Fifty safflower germplasm accessions and 20 safflower varieties were sown each in single row of 2 m with a spacing of 45 X 10 cm with 2 checks, A-1, resistant and CO-1, susceptible repeated after 10 test entries.

All the test entries were evaluated for their reaction to aphids through artificial field screening method (Srinivas and Mukta, 2015). The susceptible check, CO-1 was sown in a separate block (Infester block) one month before sowing of test entries. The test entries were sown one month after infester rows sowing with one row of susceptible CO-1 repeated after every 10 rows of test entries. The infester plants with aphids were uprooted and spread across the

E-mail: psatya.srinivas@icar.gov.in

screening block uniformly @ 1 plant per 1m test entry row, when the main crop was at stem elongation stage (35-40 days old). Aphids moved to the test entries, multiplied and caused damage symptoms within 10 days of release. When the susceptible check, CO-1 was killed completely, the damage rating was recorded on a 1-5 scale: 0 to 20 % yellowing & drying of foliage-1;21 to 40 % yellowing & drying of foliage-2; 41 to 60 % yellowing & drying of foliage- 3; 61 to 80 % yellowing & drying of foliage- 4; and 81 to 100 % yellowing & drying of foliage - 5.Injury rating was given to five randomly selected plants from each replication and aphid infestation index (AII) was calculated by using the following formula:

$$AII = \frac{1 \times a + 2 \times b + 3 \times c + 4 \times d + 5 \times e}{a + b + c + d + e}$$

Where, a, b, c, d and e are the actual number of plants falling in each of the 5 corresponding foliage drying grades i.e. 1 to 5. Finally, the mean of AII was calculated and the entries were classified into different grades as - Highly resistant (AII, 1.0), Resistant (AII, >1.0 to 2.0), Moderately resistant (AII, >2.0 to 3.0), Susceptible (AII, >3.0 to 4.0) and Highly susceptible (AII, >4.0 to 5.0).

Table 1 Reaction of safflower germplasm accessions to aphid

Germplasm accessions	Average AII	Category	Germplasm accessions	Average AII	Category
GMU-5133	2.3	MR	GMU-5163	3.8	S
GMU-5848	2.7	MR	GMU-5908	3.8	S
GMU-0599	2.8	MR	GMU-6312	3.8	S
GMU-0671	2.8	MR	GMU-7873	3.8	S
GMU-7869	2.9	MR	GMU-7881	3.8	S
GMU-3256	3.0	MR	GMU-7884	3.8	S
GMU-7868	3.0	MR	GMU-0040	3.9	S
GMU-7870	3.0	MR	GMU-0593	3.9	S
GMU-7885	3.0	MR	GMU-2969	3.9	S
GMU-7917	3.0	MR	GMU-7864	3.9	S
GMU-7867	3.3	S	GMU-0216	4.0	S
GMU-7880	3.3	S	GMU-5935	4.0	S
GMU-7863	3.4	S	GMU-7862	4.0	S
GMU-7866	3.4	S	GMU-2129	4.2	HS
GMU-7871	3.4	S	GMU-7874	4.2	HS
GMU-7888	3.4	S	GMU-6556	4.3	HS
GMU-7865	3.5	S	GMU-7861	4.4	HS
GMU-7879	3.5	S	GMU-2437	4.5	HS
GMU-7887	3.5	S	GMU-2616	4.5	HS
GMU-7890	3.5	S	GMU-0638	4.6	HS
GMU-7872	3.6	S	GMU-7883	4.6	HS
GMU-7907	3.6	S	GMU-1047	5.0	HS
GMU-2985	3.7	S	GMU-2749	5.0	HS
GMU-7877	3.7	S	GMU-3703	5.0	HS
GMU-7886	3.7	S	A-1 (RC)	3.0	MR
GMU-0095	3.8	S	CO-1 (SC)	5.0	HS

AII- Aphid Infestation Index, MR- Moderately Resistant, S- Susceptible, HS- Highly Susceptible, SC- Susceptible Check, RC- Resistant Check

Out of 50 germplasm accessions screened (Table 1), none was found resistant to aphids. Ten accessions viz., GMU-5133, GMU-5848, GMU-599, GMU-671, GMU-7869, GMU-3256, GMU-7868, GMU-7870, GMU-7885, GMU-7917 were moderately resistant with an average AII, ranging from 2.3 to 3.0. Among ten moderately resistant accessions, low AII of 2.3 was recorded on the germplasm accession GMU- 5133 and the accessions, GMU-3256, GMU-7868, GMU- 7870, GMU- 7885 and GMU-7917 recorded maximum AII of 3.0. Among twenty-nine susceptible accessions, GMU- 7867 and GMU- 7880 recorded minimum AII of 3.3 and GMU- 216, GMU- 5935 and GMU- 7862 recorded maximum AII of 4.0. Among eleven highly susceptible accessions, GMU- 2129 and GMU-7874 recorded minimum AII of 4.2 and GMU- 1047, GMU-2749 and GMU- 3703 recorded maximum AII of 5.0. The checks A-1 and CO-1 recorded AII of 3.0 and 5.0 respectively. The susceptible check, CO-1 recorded the highest A I I of 5.0 whereas, A-1, showed moderately resistant reaction to aphid with a AII of 3.0.

Table 2 Reaction of safflower varieties to aphid

Varieties	A.I.I	Reaction
Girna	2.0	R
SSF-748	2.4	MR
SSF-733	2.6	MR
Bhima	2.7	MR
A-1	2.8	MR
SSF-708	3.0	MR
PBNS-12	3.0	MR
Manjira	3.0	MR
JSF-1	4.1	HS
A-2	4.2	HS
Phule Kusum	4.2	HS
JSI-97	4.2	HS
PKV-Pink	4.5	HS
AKS-207	4.6	HS
SSF-658	4.7	HS
JSI-99	4.9	HS
Sharda	5.0	HS
NARI-6	5.0	HS
NARI-57	5.0	HS
JSI-73	5.0	HS
CO-1 (SC)	5.0	HS

A.I.I- Aphid Infestation Index, R- Resistant, MR- Moderately Resistant, HS- Highly Susceptible, SC- Susceptible Check

Out of 20 varieties evaluated (Table 2), one variety, Girna was found resistant with an average AII of 2.0. Seven varieties viz. SSF-748, Bhima, A-1, SSF-708, PBNS-12, SSF-733 and Manjira were moderately resistant to aphids with an average AII ranging from 2.3 to 3.0. Among seven moderately resistant varieties, SSF- 748 recorded minimum AII of 2.3 and SSF- 708, PBNS- 12, Manjira recorded the maximum AII of 3.0. Twelve varieties were highly susceptible to aphid (Table 2). twelve varieties were found highly susceptible (AII 4.1- 5.0). Among twelve highly susceptible varieties, JSF- 1 recorded minimum AII of 4.1 and Sharda, NARI- 6, NARI- 57 and JSI- 73 recorded maximum AII of 5.0.The susceptible check CO-1 recorded the highest AII of 5.0.Gurunath and Balikai (2018) reported A-1 as moderately tolerant variety to safflower aphids.

After confirmation of their reaction to aphids the promising safflower accessions may be useful in incorporating aphid resistance in safflower though breeding programmes. The resistant or moderately resistant safflower varieties may be used and susceptible varieties may be avoided for cultivation in areas where aphid is a regular insect pest.

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INDIAN SOCIETY OF OILSEEDS RESEARCH

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References (To be typed as above, as side heading below Acknowledgement)

The list of references must include all published work referred to in the text. Type with double line spacing. Do not cite anonymous as author; instead cite the name of the institute, publisher, or editor. References should be arranged alphabetically according to the surnames of the individual authors or first authors. Two or more references by the same author are to be cited chronologically; two or more in the same year by the letters a, b, c, etc. All individually authored articles precede those in which the individual is the first or joint author. Every reference cited in the article should be included in the list of References. This needs rigorous checking of each reference. Names of authors should not be capitalized.

The reference citation should follow the order: author(s), year of publication, title of the paper, periodical (title in full, no abbreviations, italics or underlined), volume (bold or double underlining), starting and ending pages of the paper. Reference to a book includes authors(s), year, title (first letter of each word except preposition, conjunction, and pronouns in capitals and underlined), the edition (if other than first), the publisher, city of publication. If necessary, particular page numbers should be mentioned in the last. Year of publication cited in the text should be checked with that given under References. Year, volume number and page number of each periodical cited under "References" must be checked with the original source. The list of references should be typed as follows:

Rao C R 1968. *Advances in Statistical Methods in Biometrical Research*, pp.40-45, John Wiley & Sons, New York.

Kanwar J S and Raychaudhuri S P 1971. *Review of Soil Research in India*, pp 30-36. Indian Society of Soil Science, New Delhi.

Mukherjee J N 1953. The need for delineating the basic soil and climatic regions of importance to the plant industry. *Journal of the Indian Society of Soil Science*, **1** : 1-6.

Khan S K, Mohanty S K and Chalam A B, 1986. Integrated management of organic manure and fertilizer nitrogen for rice. *Journal of the Indian Society of Soil Science*, **34** : 505-509.

Bijay-Singh and Yadvinder-Singh 1997. Green manuring and biological N fixation: North Indian perspective. In: Kanwar J S and Katyal J C (Ed.) *Plant Nutrient Needs, Supply, Efficiency and Policy Issues 2000-2025.* National Academy of Agricultural Sciences, New Delhi, India, pp.29-44.

Singh S, Pahuja S S and Malik R K 1992. Herbicidal control of water hyacinth and its effect on chemical composition of water *(in) Proceedings of Annual Weed Science Conference*, held during 3-4 March 1992 by the Indian Society of Weed Science, at Chaurdhary Charan Singh Haryana Agricultural University, Hisar, 127p.

AICRP on Soybean 1992. *Proceedings of 23rd Annual Workshop of All-India Co-ordinated Research Project on Soybean*, held during 7-9 May 1992 at University of Agricultural Sciences, Bangalore, Karnataka, National Research Centre for Soybean, Indore, pp.48.

Devakumar C. 1986. Identification of nitrification retarding principles in neem (*Azadirachta indica* A.Juss.) seeds. Ph D Thesis, Indian Agricultural Research Institute, New Delhi.

Reference to unpublished work should normally be avoided and if unavoidable it may be mentioned only in the text.

Short Communication

Conceptually short communication is a first report on new concept, ideas and methodology which the author(s) would wish to share with the scientific community and that the detailed paper would follow. Short Communication is akin to an advance booking for the report on the findings. Short communications may include short but trend-setting reports of field or laboratory observation(s), preliminary results of long-term projects, or new techniques or those matters on which enough information to warrant its publication as a full length article has still not been generated but the results need to be shared immediately with the scientific community. The style is less formal as compared with the "full-length" article. In the short communications, the sections on abstract, materials and methods, results and discussion, and conclusion are omitted; but the material is put concisely in the same sequence but without formal sections. The other instructions are the same as in the case of the full-length articles.

Tables

Tables should not form more than 20% of the text. Each table should be typed on separate sheet and should have on the top a table number (in Arabic numerals *viz*. 1, 2, 3 etc.) and a caption or title which should be short, but sufficiently explanatory of the data included in the table. Information in the table should never duplicate that in the text and vice versa. Symbols (asterisks, daggers, etc. or small letters, *viz*., a, b, etc.) should be used to indicate footnotes to tables. Maximum size of table acceptable is what can be conveniently composed within one full printed page of the journal. Over-sized tables will be rejected out-right. Such tables may be suitably split into two or more small tables.

The data in tables should be corrected to minimum place of decimal so as to make it more meaningful. Do not use full stop with CD, SEm±, NS (not C.D., S.E.m±, N.S.). Do not put cross-rules inside the table. Tables should be numbered consecutively and their approximate positions indicated in the margin of the manuscript. Tables should not be inserted in the body of the text. Type each table on a separate sheet. Do not use capital letters for the tabular headings, do not underline the words and do not use a full-stop at the end of the heading. All the tables should be tagged with the main body of the text i.e. after references.

Figures

Figures include diagrams and photographs. Laser print outs of line diagrams are acceptable while dot-matrix print outs will be rejected. Alternatively, each illustration can be drawn on white art card or tracing cloth/ paper, using proper stencil. The lines should be bold and of uniform thickness. The numbers and letterings must be stenciled; free-hand drawing will not be accepted. Size of the illustrations as well as numbers, and letterings should be sufficiently large to stand suitable reduction in size. Overall size of the illustrations should be such that on reduction, the size will be the width of single or double column of the printed page of the Journal. Legends, if any, should be included within the illustration. Each illustration should have a number followed by a caption typed/ typeset well below the illustration.

Title of the article and name(s) of the author(s) should be written sufficiently below the caption. The photographs (black and white) should have a glossy finish with sharp contrast between the light and the dark areas. Colour photographs/ figures are not normally accepted. One set of the original figures must be submitted along with the manuscript, while the second set can be photocopy. The illustrations should be numbered consecutively in the order in which they are mentioned in the text. The position of each figure should be indicated in the margin of the text. The photographs should be securely enclosed with the manuscript after placing them in hard board pouches so that there may not be any crack or fold. Photographs should preferably be 8.5 cm or 17 cm wide or double the size. The captions for all the illustrations (including photographs) should be typed on a separate sheet of paper and placed after the tables.

Expression of Plant Nutrients on Elemental Basis

The amounts and proportions of nutrient elements must be expressed in elemental forms e.g. for ion uptake or in other ways as needed for theoretical purposes. In expressing doses of nitrogen, phosphatic, and potassic fertilizers also these should be in the form of N, P and K, respectively. While these should be expressed in terms of kg/ha for field experiments, for pot culture studies the unit should be in mg/kg soil.

SI Units and Symbols

SI Units (System International d 'Unities or International System of Units) should be used. The SI contains three classes of units: (i) base units, (ii) derived units, and (iii) supplementary units. To denote multiples and sub-multiples of units, standard abbreviations are to be used. Clark's Tables: Science Data Book by Orient Longman, New Delhi (1982) may be consulted.

Some of these units along with the corresponding symbols are reproduced for the sake of convenience.

Names and Symbols of SI Units

Physical Symbol for SI Unit Symbol Remarks quantity physical quantity for SI Unit

Primary Units					
length	l		time	t	
metre	m		second	s	
mass	m		electric current	I	
kilogram	kg		ampere	A	
Secondary Units					
plane angle	radian	rad	Solid angle	steradian	sr
Unit Symbols					
centimetre	cm		microgram	μg	
cubic centimetre	cm^3		micron	μm	
cubic metre	m^3		micronmol	μmol	
day	d		milligram	mg	
decisiemens	dS		millilitre	mL	
degree-Celsium	°C [=(F-32)x0.556]		minute	min	

gram	g	nanometre	nm
hectare	ha	newton	N
hour	h	pascal	Pa
joule J	(= 10^7 erg or 4.19 cal.)	second	s
kelvin	K (= °C + 273)	square centimetre	cm^2
kilogram	kg	square kilometre	km^2
kilometre	km	tonne	t
litre	L	watt	W
megagram	Mg		

Some applications along with symbols

adsorption energy	J/mol (=cal/molx4.19)	leaf area	m^2/kg
cation exchange capacity	cmol (p+)/kg (=m.e./100 g)	nutrient content in plants (drymatter basis)	μg/g, mg/g or g/kg
Electrolytic conductivity	dS/m (=mmhos/cm)	root density or root length density	m/m^3
evapotranspiration rate	$m^3/m^2/s$ or m/s	soil bulk density	Mg/m^3 (=g/cm^3)
heat flux	W/m^2	specific heat	J/kg/K
gas diffusion	$g/m^2/s$ or $m^3/m^2/s$ or m/s	specific surface area of soil	m^2/kg
water flow	$kg/m^2/s$ (or) m^3m^2s (or) m/s	thermal conductivity	W/m/K
gas diffusivity	m^2/s	transpiration rate	$mg/m^2/s$
hydraulic conductivity ion uptake	m/s	water content of soil	kg/kg or m^3/m^3
(Per kg of dry plant material)	mol/kg	water tension	kPa (or) MPa

While giving the SI units the first letter should not be in capital i.e cm, not Cm; kg not Kg. There should not be a full stop at the end of the abbreviation: cm, not cm. kg, not kg.; ha, not ha.

In reporting the data, dimensional units, viz., M (mass), L (length), and T (time) should be used as shown under some applications above. Some examples are: 120 kg N/ha; 5 t/ha; 4 dS/m etc.

Special Instructions

I. In a series or range of measurements, mention the unit only at the end, e.g. 2 to 6 cm2, 3, 6, and 9 cm, etc. Similarly use cm2, cm3 instead of sq cm and cu m.

II. Any unfamiliar abbreviation must be identified fully (in parenthesis).

III. A sentence should not begin with an abbreviation.

IV. Numeral should be used whenever it is followed by a unit measure or its abbreviations, e.g., 1 g, 3 m, 5 h, 6 months, etc. Otherwise, words should be used for numbers one to nine and numerals for larger ones except in a series of numbers when numerals should be used for all in the series.

V. Do not abbreviate litre to` l' or tonne to `t'. Instead, spell out.

VI. Before the paper is sent, check carefully all data and text for factual, grammatical and typographical errors.

VII. Do not forget to attach the original signed copy of `Article Certificate' (without any alteration, overwriting or pasting) signed by all authors.

VIII. On revision, please answer all the referees' comments point-wise, indicating the modifications made by you on a separate sheet in duplicate.

IX. If you do not agree with some comments of the referee, modify the article to the extent possible. Give reasons (2 copies on a separate sheet) for your disagreement, with full justification (the article would be examined again).

X. Rupees should be given as per the new symbol approved by Govt. of India.

Details of the peer review process

Manuscripts are received mainly through e-mails and in rare cases, where the authors do not have internet access, hard copies of the manuscripts may be received and processed. Only after the peer review the manuscripts are accepted for publication. So there is no assured publication on submission. The major steps followed during the peer review process are provided below.

Step 1. *Receipt of manuscript and acknowledgement*: Once the manuscript is received, the contents will be reviewed by the editor/associate editors to assess the scope of the article for publishing in JOR. If found within the scope of the journal, a Manuscript (MS) number is assigned and the same will be intimated to the authors. If the MS is not within the scope and mandate of JOR, then the article will be rejected and the same is communicated to the authors.

Step 2. *Assigning and sending MS to referees*: Suitable referees will be selected from the panel of experts and the MS (soft copy) will be sent to them for their comments - a standard format of evaluation is provided to the referees for evaluation along with the standard format of the journal articles and the referees will be given 4-5 week time to give their comments. If the comments are not received, reminders will be sent to the referees for expediting the reviewing process and in case there is still no response, the MS will be sent to alternate referees.

Step 3. *Communication of referee comments to authors for revision*: Once the referee comments and MS (with suggestions/ corrections) are received from the referees, depending on the suggestions, the same will be communicated to the authors with a request to attend to the comments. Authors will be given stipulated time to respond and based on their request, additional time will be given for attending to all the changes as suggested by referees. If the referees suggest no changes and recommend the MS for publication, then the same will be communicated to the authors and the MS will be taken up for editing purpose for publishing. In case the referees suggest that the article cannot be accepted for JOR, then the same will be communicated to the authors with proper rationale and logic as opined by the referees as well as by the editors.

Step 4. *Sending the revised MS to referees*: Once the authors send the revised version of the articles, depending on the case (like if major revisions were suggested by referees) the corrected MS will be sent to the referees (who had reviewed the article in the first instance) for their comments and further suggestions regarding the acceptability of publication. If only minor revisions had been suggested by referees, then the editors would look into the issues and decide take a call.

Step 5. *Sending the MS to authors for further revision*: In case referees suggest further modifications, then the same will be communicated to the authors with a request to incorporate the suggested changes. If the referees suggest acceptance of the MS for publication, then the MS will be accepted for publication in the journal and the same will be communicated to the authors. Rarely, at this stage also MS would be rejected if the referees are not satisfied with the modifications and the reasoning provided by the authors.

Step 6. *Second time revised articles received from authors and decision taken*: In case the second time revised article satisfies all the queries raised by referees, then the MS will be accepted and if not satisfied the article will be rejected. The accepted MS will be taken for editing process where emphasis will be given to the language, content flow and format of the article.

Then the journal issue will be slated for printing and also the pdf version of the journal issue will be hosted on journal webpage.

Important Instructions

- Data on field experiments have to be at least for a period of 2-3 years
- Papers on pot experiments will be considered for publication only as short communications
- Giving coefficient of variation in the case of field experiments Standard error in the case of laboratory determination is mandatory. For rigorous statistical treatment, journals like Journal of Agricultural Science Cambridge, Experimental Agriculture and Soil Use and Management should serve as eye openers.

SPECIAL ANNOUNCEMENT

In a recently conducted Executive Committee meeting of the Indian Society of Oilseeds Research, it was decided to increase the scope of the Journal of Oilseeds Research by accommodating vibrant aspects of scientific communication. It has been felt that, the horizon of scientific reporting could be expanded by including the following types of articles in addition to the Research Articles, Shor Communications and Review Articles that are being published in the journal as of now.

Research accounts (not exceeding 4000 words, with cited references preferably limited to about 40-50 in number): These are the articles that provide an overview of the research work carried out in the author(s)' laboratory, and be based on a body of their published work. The articles must provide appropriate background to the area in a brief introduction so that it could place the author(s)' work in a proper perspective. This could be published from persons who have pursued a research area for a substantial period dotted with publications and thus research account will provide an overall idea of the progress that has been witnessed in the chosen area of research. In this account, author(s) could also narrate the work of others if that had influenced the course of work in authors' lab.

Correspondence (not exceeding 600 words): This includes letters and technical comments that are of general interest to scientists, on the articles or communications published in Journal of Oilseeds Research within the previous four issues. These letters may be reviewed and edited by the editorial committee before publishing.

Technical notes (less than 1500 words and one or two display items): This type of communication may include technical advances such as new methods, protocols or modifications of the existing methods that help in better output or advances in instrumentation.

News (not exceeding 750 words): This type of communication can cover important scientific events or any other news of interest to scientists in general and vegetable oil research in particular.

Meeting reports (less than 1500 words): It can deal with highlights/technical contents of a conference/ symposium/discussion-meeting, etc. conveying to readers the significance of important advances. Reports must

Meeting reports should avoid merely listing brief accounts of topics discussed, and must convey to readers the significance of an important advance. It could also include the major recommendations or strategic plans worked out.

Research News (not exceeding 2000 words and 3 display items): These should provide a semi-technical account of recently published advances or important findings that could be adopted in vegetable oil research.

Opinion (less than 1200 words): These articles may present views on issues related to science and scientific activity.

Commentary (less than 2000 words): This type of articles are expected to be expository essays on issues related directly or indirectly to research and other stake holders involved in vegetable oil sector.

Book reviews (not exceeding 1500 words): Books that provide a clear in depth knowledge on oilseeds or oil yielding plants, production, processing, marketing, etc. may be reviewed critically and the utility of such books could be highlighted.

Historical commentary/notes (limited to about 3000 words): These articles may inform readers about interesting aspects of personalities or institutions of science or about watershed events in the history/development of science. Illustrations and photographs are welcome. Brief items will also be considered.

Education point (limited to about 2000 words): Such articles could highlight the material(s) available in oilseeds to explain different concepts of genetics, plant breeding and modern agriculture practices.

Note that the references and all other formats of reporting shall remain same as it is for the regular articles and as given in Instructions to Authors

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