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RESEARCH PAPER

Yield and yield attributes of safflower in integrated nutrient management in black gram (*Vigna mungo* L.) - Safflower (*Carthamus tinctorius* L.) crop sequence

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Abstract : An experiment on integrated nutrient management in black gram - safflower crop sequence was conducted at DFRS, Solapur for four years (1910-11 to 1913-14) with the objective to integrate the different sources of plant nutrients for safflower based cropping system to economize fertilizer use and sustain productivity. The fertilizer dose of 100 per cent NP to both the crops in sequence recorded significantly higher seed equivalent yield (2456 kg ha^{-1}). Whereas, treatment with 100 % N+ 50 % P +PSB to blackgram followed by 100 per cent NP to safflower was at par with it (2285 kg ha^{-1}). Plant height (103.4 cm) and total dry matter (53.41 g plant^{-1}) were reported significantly superior under 100 % N + 50 % P + PSB to blackgram and 100 per cent NP to safflower. Number of branches and number of capitulas per plant were noticed higher in treatment with 100 per cent NP to both the crops. Higher volume weight (755 g) was noticed under 100 per cent NP to blackgram and 50 % N + *Azotobacter* + 100 % P to safflower. Higher net returns of Rs. 43683/ha and B:C ratio of 2.33 were recorded under 100 % N+ 50% P +PSB to blackgram followed by 100 per cent NP to safflower. Second in order were under 100 % N + 50 % P + PSB to blackgram and 50 % NP + *Azotobacter* + PSB to safflower with Rs. 41871 and 2.27 net returns and BC ratio, respectively.

Key Words : *Azotobacter*, Crop sequence, Equivalent yield, INM, PSB

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INTRODUCTION

Safflower (*Carthamus tinctorius* L.), an oilseed crop is a member of the family Compositae or Asteraceae. Carthamus is the latinized synonym of the Arabic word quartum or gurtum, which refers to the colour of the dye extracted from safflower flowers. Safflower has been grown in India since time immemorial. It has been grown for centuries in India for the orange-red dye (carthamin) extracted from its brilliantly colored flowers and for its quality oil rich in polyunsaturated fatty acids (linoleic acid, 78%). Safflower flowers are known to have many medicinal properties for during several chronic diseases, and they are widely used in Chinese herbal preparations (Li and Mundel, 1996). Safflower (*Carthamus tinctorius* L.) is bestowed with a unique feature of salt as well as drought tolerance due to partially

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xerophytic nature, in addition to deep and extensive root system making efficient use of reserved soil moisture and available nutrients of various depths. It can safely be grown during the post rainy season as a potential *Rabi* crop in unirrigated areas (Emami *et al.,* 2011). It fevours cool and dry weather during it's growth period. India ranks first in area (41%) and production (29%) of the safflower grown across the world. In India, safflower is grown in 1.78 lakh ha and production is 1.44 lakh tons. In Maharashtra, safflower is grown in 1.07 lakh hactares with a production of about 61,000 tons, with a productivity of 570 kg ha^{-1} (Anonymous, 2015). This is 60.11 and 53.5 per cent of India's area and production. Inclusion of legumes in the cropping system has been known since times immemorial. Legume is a natural mini-nitrogen manufacturing factory in the field and the farmers by growing these crops can play a vital role in increasing indigenous nitrogen production. Legume help in solublizing insoluble P in soil, improving the soil physical environment, increasing soil microbial activity, and restoring organic matter (Singh, 1983). In a country like India, where the average consumption of plant nutrients from chemical fertilizers on national basis is very low, the scope for exploiting direct and residual fertility due to legumes has obviously a great potential (Ghosh *et al.*, 2007). Decreasing soil fertility has raised the concerns about the sustainability of agricultural production at current levels. Further, strategies for increasing productivity will have to focus on using available nutrient resources more efficiently, effectively and sustainable than in the past. Integrated management of the nutrients needed for proper plant growth together with effective crop, water, soil and land management will be critical for sustaining agriculture over long term. Owing to the ever increasing cost of inorganic chemical fertilizers, the integration of inorganic fertilizers with organic manures and crop residues has become imperative for sustained crop production and maintenance of soil health (Babulkar *et al.,* 2000). The inclusion of blackgram can be fit well in crop sequence due it's characteristics *viz.*, short duration, improving soil nutrient status and addition of crop residue for next crop. Hence, a field experiment was conducted to study the effect of integrated nutrient management in this sequence on *vertisols* under rainfed conditions of Maharashtra.

MATERIAL AND METHODS

The field experiment was conducted for four consecutive years (2010-11 to 2013-14) at dry farming research station, Solapur (M.S.) on fixed experimental site. The centre comes under scarcity zone and geographically situated at 17º 41´ North latitude and 75º 56´ East longitude at 483.6 meter above mean sea level (MSL). The rainfall of this region is characterized by inadequate, ill distributed and undependable erratic nature. The annual normal rainfall is 723.4 mm in 40 to 45 rainy days while, the *Kharif* and *Rabi* normals are 420.7 and 237.8 mm. Initially the composite soil sample was analyzed in laboratory for the determination of fertility status following standard analytical procedures. The experimental site was low in available N (112.4 kg ha^{-1}), medium in available P_2O_5 (16.23 kg ha^{-1}) and higher in available K_2O (326 kg ha^{-1}). The organic carbon content was low (0.42 %) with alkaline pH (8.2) and electrical conductivity of 0.21 dS m^{-1} and belongs to *vertisol* with *montmorillonite* as dominant clay mineral. The treatments consisted of control (No NP), 50 per cent NP, 100 per cent NP of recommended dose of fertilizer (25:50:0 kg NPK ha^{-1}) and along with PSB in treatment T_{11} and T_{12} to blackgram during *Kharif* season. While 0, 50 and 100 per cent nitrogen and phosphate along with different sources of biofertilizers like *Azotobacter* and phosphate solublizing bacteria (PSB) were used in combination with inorganic fertilizers to safflower were allocated during *Rabi* season. Control (no NP) and application of 100 per cent NP (100 % N and P through inorganic fertilizer) were also included in treatments. In total, there were twelve treatments which were laid out in a Randomized Block Design and replicated thrice. Varieties TAU- 1 (black gram) and SSF-708 (safflower) were used for the study. Blackgram crop was sown during second fortnight of June to First fortnight of July after sufficient rainfall (not less than 50 mm in a week) and harvested after attaining the physiological maturity. Plot wise yield data were recorded by following appropriate procedures. Safflower was sown after the harvest of blackgram on fixed plots every year. All the agronomic practices were adopted to raise the crop. Data on yield and yield attributes of safflower were recorded after harvest of safflower. Plant height was measured and recorded at main stem upto the start of primary capitula and the primary, secondary and tertiary branches were counted separately and summed to get total number of branches per plant. System economics were calculated by considering both the crops and the safflower seed equivalent yield was calculated by considering the prevailing market rates of both the commodities and using following formula :

SSEY = (Ya × Yar) + (Yb × Ybr) / Yar

where, a= Yield of safflower, b= Yield of black gram r = Selling price of respective crops

RESULTS AND DISCUSSION

The pooled mean data of four years on seed yield of black gram and safflower are presented in Table 1. Data revealed that, an application of recommended dose of fertilizers (T_5: 100 % NP) to each crop during individual year had significantly superior in producing the significantly higher seed yield of black gram and safflower. The respective yield figures registered under this treatment was 904 and 1169 kg ha^{-1}, respectively. In blackgram, all the treatments except control (T_1) and 50 per cent NP (T_2 and T_3) were at par with each other. In case of safflower, treatments received 100 per cent NP (T_5 and T_{11}) was significantly higher in seed yield (1169 kg ha^{-1}) and was at par with 50 % NP + seed treatment with *Azotobacter* and PSB (T_{12}). The safflower seed equivalent, an expression of sequence in terms of productivity, an application of 100 per cent NP to both the crops in the sequence registered the significantly higher safflower seed equivalent (2456 kg ha^{-1}). Second in order was 100 % N + 50 % P+ PSB to blackgram and 100 NP to safflower and third in row treatment received 100 % N +50 % P+ PSB to blackgram and 50 % NP + *Azotobacter* + PSB to safflower (2214 kg ha^{-1}). Other treatments failed to exert the significant yield level. Cultivation of safflower in sequence, found benefitted by litters of previous crop. The crop residue helped in improving the soil organic matter as soil organic matter is a major source of plant nutrients and improves physical properties of soil, such as soil porosity, structure and water-holding capacity (Mando, 1998). Significantly higher seed equivalent under recommended dose of fertilizers to both the crops might supply the primary plant nutrients at the time of sowing helped the plant to attain an early boost and better growth. The soils of the scarcity zone are deficit in available nitrogen and moderate in phosphate. Hence, the crop responded quickly to the applied inorganic fertilizers. An early stimulation to growth might have resulted in early and increased root growth which enabled the plant to absorb soil moisture from different layers of soil profile. This could be one of the reasons of higher seed yield of individual crops as well as in equivalent yield under 100 per cent NP (T_5) to both crops. Better seed yield recorded under T_{11} and T_{12}, where the seeds were treated with the bio inoculants like *Azotobacter* and phosphate solublizing bacteria (PSB), were found to be have a beneficial effect on seed equivalent yield. The respective yield figures were 2285 and 2214 kg ha^{-1}. This could be attributed to their

Table 1 : Yield and economics of safflower as influenced due to various INM treatments. (Pooled data of 4 years)

Treatments			Mean yield (kg ha^{-1})		Safflower equivalent yield (kg ha^{-1})	System Economics		
	Black gram (*Kharif*)	Safflower (*Rabi*)	Black Gram	Safflower		Net returns (Rs. ha^{-1})	Cost of culti. (Rs. ha^{-1})	B:C Ratio
T_1	No NP	No NP	473	630	1228	17060	23102	1.59
T_2	50% NP	50% NP	638	812	1548	23984	26224	1.77
T_3	50% NP	100 % NP	669	958	1802	29298	28026	1.93
T_4	100% NP	50% NP	768	906	1955	32908	29006	2.02
T_5	100% NP	100% NP	904	1169	2456	38449	30934	2.15
T_6	100%NP	50% N, 100% P	799	951	2012	34653	29730	2.03
T_7	100% NP	*Azotobacter* +100% P	777	815	1849	30419	28531	1.94
T_8	100% NP	50% N+ *Azotobacter* +100% P	785	954	2016	34370	29686	2.04
T_9	100% NP	*Azotobacter* + PSB	789	802	1862	31692	28047	1.99
T_{10}	100% NP	50% NP + *Azotobacter* + PSB	794	911	1929	30603	28969	1.99
T_{11}	100% N+ 50% P + PSB	100% NP	859	1129	2285	43683	31524	2.33
T_{12}	100 % N + 50% P + PSB	50% NP + *Azotobacter* + PSB	785	1099	2214	41871	30046	2.27
	S.E ±		46.6	42.05	68.53			
	C.D. (P=0.05)		133	123.3	284.99			
	CV %		10.4	13.8	16.1			

Table 2 : Yield contributing characters of safflower as influenced due to INM treatments (Pooled data of 4 years)

Treatments			Yield attributes					
	Black gram (*Kharif*)	Safflower (*Rabi*)	Plant height (cm)	Number of branches plant^{-1}	Number of capitulas plant^{-1}	Total dry matter plant^{-1}	100 seed weight (g)	Volume weight (g)
T_1	No NP	No NP	73.5	5.4	11.8	29.18	4.68	731
T_2	50% NP	50% NP	84.9	6.3	17.6	33.39	4.73	744
T_3	50% NP	100 % NP	91.8	8.7	16.2	41.83	4.88	748
T_4	100% NP	50% NP	87.6	7.2	14.8	36.19	4.81	739
T_5	100% NP	100% NP	94.3	13.8	27.3	51.32	4.89	747
T_6	100%NP	50% N, 100% P	89.5	8.1	16.8	41.38	4.93	751
T_7	100% NP	*Azotobacter* +100% P	89.2	7.4	15.4	39.15	4.69	729
T_8	100% NP	50% N+ *Azotobacter*+ 100% P	88.6	9.8	19.6	43.38	4.78	756
T_9	100% NP	*Azotobacter* + PSB	81.7	8.6	18.4	42.16	4.61	718
T_{10}	100% NP	50% NP + *Azotobacter*+ PSB	95.3	10.7	22.6	46.15	4.81	741
T_{11}	100% N+ 50% P + PSB	100% NP	103.4	12.4	23.9	53.41	4.94	755
T_{12}	100 % N + 50% P + PSB	50% NP + *Azotobacter*+PSB	99.7	10.9	20.6	49.18	4.87	749
	S.E. ±		3.2	1.18	2.44	1.72	0.18	2.29
	C.D. (P=0.05)		10.8	3.5	7.4	5.24	NS	6.97

NS=Non-significant

capacity of carrying living micro-organisms derived from the root or cultivated soil and are capable of making available to the plants the atmospheric nitrogen fixation and phosphate solubilisation. This also helps in stimulating the plant growth hormones providing better nutrient uptake and increased tolerance towards drought and moisture stress (Anandaraj and Delapierre, 2010). Beneficial effects of *Azotobacter* on plants are attributed mainly to an improvement in root development, an increase in the rate of water and mineral uptake by roots, displacement of fungi and plant pathogenic bacteria and, to a lesser extent, biological nitrogen fixation (Okon and Itzigshohn, 1995).

Perusal to the data (Table 1) on system economics revealed that numerically higher net returns of Rs. 43683 ha^{-1} with B:C ratio 2.33 was noticed under T_{11}. The cost incurred on cultivation under T_{11} was Rs. 31524 ha^{-1}. Treatment T_{12} was second in order with net returns of Rs. 41871 ha^{-1} with B: C ratio of 2.27. Treatment T_5 (100 % NP to both crops) received the net returns of Rs. 38449 ha^{-1} with the B C ratio of 2.15.

Data on yield contributing characters of safflower due to integration of treatments are presented in Table 2. The data revealed that, plant height, number of branches and capitulas per plant and total dry matter per plant (TDM) were influenced significantly due to various treatments. Treatment received 100 % N +50 % P+ PSB to blackgram and 100 per cent NP to safflower (T_{11}) found superior in plant height (103.4 cm) and TDM (53.41 g plant^{-1}) and second in orders were T_5, T_{10} and T_{12}. While, the number of branches (13.8) and capitulas (27.3) per plant were reported significantly higher under treatment with 100 % NP (T_5) to both the crops and followed closely by treatments T_{10}, T_{11} and T_{12}. Balanced and timely supply of primary plant nutrients and increased organic carbon due to preceding blackgram residues might have helped the safflower to enhance the activities of plant growth promoting rhizobacteria (PGPR) (Mirzaei *et al.*, 2010). Bioinoculants significantly improved soil physico-chemical characters via modifying the soil environment to hold more moisture and nutrients, better aeration and microbial activity influencing nutrient uptake and improving growth components of safflower. These results tend to support the results of Nalatwadmath *et al.* (2003).

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