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Integrated Nutrient Management of Safflower (*Carthamus tinctorius* L.) under Rainfed Conditions

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Abstract

Optimistic and sustainable supply of soil available nutrients to crop plants enhances productivity. Integrated nutrient management (INM) approach can improve soil fertility on long term basis. The present study was conducted to determine effects of INM on quantitative and qualitative characters of two Safflower (*Carthamus tinctorius* L.) cultivars "Thori-78 and Leed-00". Five treatments using different composition of poultry litter, farm yard manure, nitrogen and phosphorous fertilizers with recommended dose as a control measure were replicated thrice in randomized complete design. The results of field trial depicted maximum plant height (174.6 cm), number of heads plant^{-1} (42.67), number of seeds head^{-1} (59.0), thousand seed weight (42.26 g), biological yield (3089 Kg·ha^{-1}) and seed yield (455.2 Kg·ha^{-1}) recorded from combined application of FYM @ 2 t·ha^{-1}and Half (N-P) (soil application) (T_5) in Genotype "Leed-00" which was statistically different from all other treatments. Thori-78 also showed increase in yield and yield components under the same treatment (T_5) *i.e.*2 t·ha^{-1} FYM and Half (N-P).No effect of INM was found on fatty acid composition of safflower cultivars. The correlation coefficients illustrated positive and significant association of seed yield with plant height (0.89), number of heads pod^{-1} (0.86) and number of seeds head^{-1} (0.83) as a result of application of selected treatment. These results demonstrated the significance of INM in safflower yield improvement under rainfed conditions.

Keywords

Safflower, Integrated Nutrient Management (INM), Yield, Rainfed

1. Introduction

Safflower can be cultivated as an oil seed crop under poor environmental conditions to increase the edible oil sources [1]. Safflower seed contains 35% oil contents and occupies a unique position among oil seed crops due to the high linoleic acid content of its seed oil [2].

Safflower is multipurpose crop with unexplored potential and worldwide adaptability. Safflower acreage and production has been witnessing wide fluctuations around the world. Low productivity of safflower is a serious concern for sustainable crop development. A negative growth rate in terms of area, production and productivity has been recorded around the world, especially in Pakistan. Safflower is a high value crop due to its immense potential for use in domestic, medicinal and commercial use [3].

Safflower oil contains unsaturated fatty acids including linoleic, oleic and saturated fatty acids as palmitic and stearic acid. It is one of the richest sources of linoleic acid among the commercial oils [4]. Safflower seed oil contains about 71% - 75% linoleic acid, 16% - 20% oleic acid, 6% - 8% palmitic acid, and 2% - 3% stearic acid [5]. This low level stearic and palmitic acids has madesaf flower oil appealing to consumers, initially as quick-drying oil, more recently as edible oil with the highest linoleic acid.

Plant nutrients in soil whether naturally endowed or artificially maintained are major determinants of the success or failure of a crop production system. Proper soil fertility management is of prime importance to increase crop production. Post-green revolution period has seen a tremendous rise in the use of fertilizers for enhancing productivity of field crops. This has resulted not only the deterioration of land resources but also contaminating the environment at the same time raising the cost of production [6].

Integrated nutrient management is an emerging method for sustainable agricultural production that poses the least threat to the environment disruption. Blending of inorganic fertilizer is a vital component of integrated nutrient management, yet it is often not available to farmers in developing nations [7]. Use of organic manures, apart from improving physical and biological properties of soil, facilitates efficient utilization of chemical fertilizers [8]. Combined use of organic and synthetic fertilizers in appropriate ratio is advantageous in escalating the crop yield and sustaining soil health [9]. Morphological and physiological performance of crop plants in response to INM can help in evaluating the suitability of the particular INM technique as no systematic study has been conducted on this particular crop. The present investigation was therefore undertaken to observe the effects of different integrated nutrient management combinations on performance of yield and oil quality of safflower cultivars under rainfed conditions.

2. Materials and Methods

2.1. Site Description

The response of safflower to integrated nutrient management combinations

were studied at Research Farm, Arid Agriculture University, Chakwal Road (32.93˚N, 72.86˚E) during the Rabi season, 2010-2011 under rainfed conditions. Previously fallowed field was prepared by ploughing three times with tractor mounted cultivator and planking with last ploughing. Sowing was done with hand drill on November 22, 2010 with the seed rate of 15 kg·ha^{-1}. The plot size was 5 × 3.6 m^2. Row to row distance was 60 cm and plant to plant distance was maintained at 10 cm.

2.2. Experimental Design

Safflower cultivar Thori-78 being spineless, high yielding and early maturing cultivar of Pakistan and Leed-00 belongs to USA (United States of America) having good yield potential and spiny nature were used as experimental material. Six different nutrient management combinations control (T_1), Recommended Dose N-P (30 - 35 Kg·ha^{-1}) (T_2), FYM 2 t·ha^{-1} (T_3), Poultry Litter 2 t·ha^{-1} (T_4), Half (N-P) + 2 t·ha^{-1} FYM (T_5) and Half (N-P) + 2 t·ha^{-1} Poultry Litter (T_6) in split plot design with four replications having cultivars in main plots and nutrient treatments in sub plots were used. Characteristics of farmyard manure and poultry manure used as organic fertilizer are given in Table 1(a) and Table 1(b). Climatic data during the experimental period at the experimental farm is presented in Figure 1.

2.3. Measurements

Data were recorded for quantitative characters of safflower like plant height (cm), number of heads plant^{-1}, number of seeds head^{-1}, thousand seed weight (g), biological yield (Kg/ha) and seed yield (Kg/ha) at harvesting, done on 26th

Table 1. (a) Soil characteristics of the experimental site prior to sowing; (b) Characteristics of Farmyard Manure and Poultry Manure used as Organic Fertilizer in the Experiment.

(a)

N (mg·kg^{-1})	P (mg·kg^{-1})	K (mg·kg^{-1})	EC (dS·m^{-1})	OM (%)
0.44	2.5	134.5	0.45	0.82

(b)

Sr. #	Nutrients	Farmyard Manure	Poultry Manure
1.	Nitrogen (N)%	2.34	0.6
2.	Phosphorous (P)%	0.68	1.05
3.	Sodium (Na) c·mol·kg^{-1}	0.88	0.84
4.	Potassium (K) c·mol·kg^{-1}	7.51	10.12
5.	Calcium (Ca) c·mol·kg^{-1}	14.26	9.79
6.	Magnesium (Mg) c·mol·kg^{-1}	13.74	0.63
7.	Moisture%	80	53

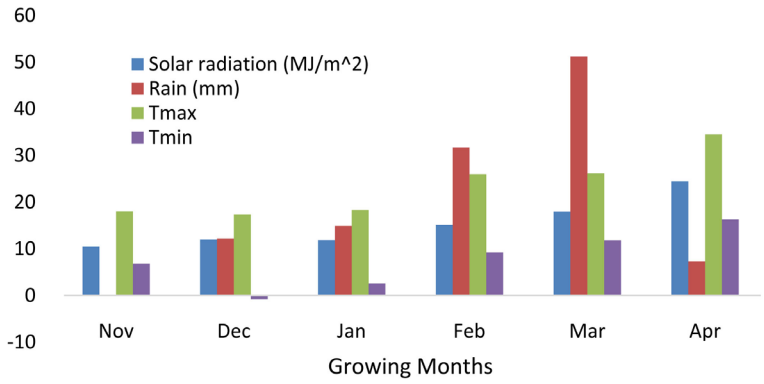

Figure 1. Climatic data during the experimental period at the experimental farm from November, 2010 to April, 2011.

April 2011. Data recorded for different parameters were subjected to statistical analysis using R software by computing analysis of variance.

2.4. Oil Content

Oil extraction was carried out using Soxhlet apparatus [10] [11].

2.5. Fatty Acid Composition

Fatty acid composition of seed samples (stearic, palmitic, oleicand linoleic) was determined through gas chromatograph by methylating the fatty acyl-esters in the oil. The composition and identification of fatty acid was carried out by the relative retention times of the standards [12] [13].

The means were analyzed and compared at $p \leq 0.05$ by F-protected least significant difference test (LSD). The simple correlation coefficients (r) of grain yield with other yield components were also worked out according to [14].

3. Results and Discussion

3.1. Plant Height (cm)

The mean data regarding plant height of safflower (**Table 2**) showed that it was significantly affected by different treatments. Maximum plant height (170.0 cm) was recorded with [Half (N-P) + FYM @2 t·ha^{-1} (T_5)] followed by T_3 (166.9 cm) and T_4 (166.0 cm) while minimum plant height (142.6 cm) was observed in T_1 (Control). The plants with maximum height (174.6 cm) were observed for cultivar Leed-00, whereas the minimum height (134.0 cm) was recorded for local cultivar Thori-78. Significant variation in plant height might be due to genetic factor as the cultivars were of different origin. Similar results were obtained by [15] who concluded that combined application of organic and inorganic fertilizer significantly increased the plant height. These results are in conformity with [16] [17] who stated that differences among the plant height might be due to nutrient status and availability thus plants responded to the treatments according to the nutrient supply.

Table 2. Response of Safflower to integrated nutrient management.

Treatments	Plant Height (cm)	Number of Heads Plant^{-1}	Number of Seeds Head^{-1}	Thousand Seed weight (g)	Biological Yield (Kg/ha^{-1})	Seed Yield (Kg/ha^{-1})
T_1	142.6 b	20.83 d	28.33 d	32.55 d	1951 cd	319.8 d
T_2	150.3 ab	23.00 cd	32.33 cd	37.87 c	1900 d	330.1 cd
T_3	166.9 a	32.00 b	46.50 a	40.3 b	2790 ab	402.6 ab
T_4	166.0 a	28.67 bc	40.17 b	40.04 b	2762 ab	383.3 abc
T_5	170.0 a	39.50 a	48.67 a	42.17 a	3034 a	435.7 a
T_6	156.3 ab	24.50 cd	33.67 c	37.50 c	2387 bc	343.1 bcd

At 0.05 level of significance. Any two means sharing same letters are statistically non-significant

3.2. Number of Heads Plant^{-1}

Data presented in Table 2 depicted maximum (39.50) number of heads plant^{-1} from T_5 followed by T_3 (32.0) and T_4 (28.67) which was statistically significant compared to T_1 (control), T_2 and T_6 where minimum (20.83, 23.00 and 24.50) heads were observed. The cultivars Leed-00 and Thori-78 recorded the maximum (42.67) and (36.33) heads per plant with T_5, while T_1 showed minimum count for number of heads per plant *i.e.* (21.00 and 20.67) Table 3. Better availability of nutrients may result in better crop growth rate and ultimately more number of heads in safflower. Statistically significant differences were observed among the interaction of cultivars and treatments. These results are also in line with the findings of [15] [18] who reported that organic fertilizers ensures better availability of nutrients which produced better crop development and also number of pods per plant.

3.3. Number of Seeds Head^{-1}

There were significant differences among the treatments for number of seeds per head (Table 2). The maximum (48.67) seeds were recorded when FYM was applied in combination with NP, whereas, the minimum (28.33) seeds per head were observed in T_1 (control), rest of treatments were statistically different with each other.Leed-00 produced maximum (59.0) and Thori-78 minimum (38.33). Maximum number of seeds per head for Leed-00 andThori-78 were recorded (59.00, 38.33) in T5 followed by T3. Tested cultivars were statistically different for number of seeds per head which might be due to their different genetic makeup and their response to available soil nutrients [19] [20] also stated significant increase in the number of seeds in safflower as result of INM. The results are also in the line with [20] [21] who reported integrated use of organic and inorganic fertilizers significantly increased the number of seeds per head.

3.4. Thousand Seed Weight (g)

The data regarding 1000-seed weight (Table 2) showed maximum value (42.26 g) from treatment (half (N-P) + FYM @ 2 ton·ha^{-1}) (T_5) followed by T_3 (40.32 g)

Table 3. Response of safflower cultivars to integrated nutrient management.

	Plant Height		Number of Heads Plant^{-1}		Number of Seeds Head^{-1}		Thousand Seed weight (g)		Biological Yield (Kg/ha^{-1})		Seed Yield (Kg/ha^{-1})	
Treatments	Thori-78	Leed-00	Thori-78	Leed-00	Thori-78	Leed-00	Thori-78	Leed-00	Thori-78	Leed-00	Thori-78	Leed-00
T_1	134.0 c	151.2 abc	20.67 e	21.00 e	26.67 e	30.00 de	32.60 d	32.50 d	1860 de	2042 cde	317.6 cd	322.0 cd
T_2	141.4 bc	159.2 abc	23.67 de	22.33 de	33.67 cd	31.00 de	37.87 bc	37.87 bc	2316 bcd	1484 e	311.7 d	348.6 bcd
T_3	161.6 abc	172.2 ab	32.00 bc	32.00 bc	38.33 bc	54.67 a	40.53 a	40.10 ab	2949 ab	2631 abc	394.2 abcd	411.0 ab
T_4	163.5 abc	168.5 ab	29.67 bcd	27.67 cde	36.00 cd	44.33 b	40.03 ab	40.05 ab	2938 ab	2586 abc	367.2 bcd	399.4 abc
T_5	165.4 abc	174.6 a	36.33 ab	42.67 a	38.33 bc	59.00 a	42.08 a	42.26 a	2978 ab	3089 a	416.2 ab	455.2 a
T_6	150.9 abc	161.6 abc	26.33 cde	22.67 de	34.33 cd	33.00 cd	37.54 c	37.47 c	2415 bcd	2359 bcd	314.0 d	372.2 abcd

At 0.05 level of significance. Any two means sharing same letters are statistically non-significant.

and T_4 (40.04 g), while the minimum seed weight (32.55 g) was under T_1 (control), furthermore, T_2 and T_6 remained non-significant. Interactive effects for treatments verses cultivars were statistically significant for thousand seed weight. The maximum 1000-seed weight (42.26 g) was observed in Leed-00 by T_5.while Thori-78 showed (42.08 g) 1000-seed weight by the same treatment (T_5). Superior performance of safflower cultivars could be attributed to the more availability of nutrients from farm yard manure applied in combination with inorganic fertilizers [22] (Kubsad *et al*., 2008). Similar trend was found in the findings of [15] [23] who observed significant differences for 1000 seed weight in safflower by the combined application of synthetic and farm yard manure fertilizers.

3.5. Biological Yield (Kg/ha)

Biological yield is a combination of seed yield and straw yield and is direct index of photosynthetic machinery. It becomes more important for multipurpose crop like safflower as the high biological yield will not only provide good seed yield but also more dry matter can be used for fodder purpose. The safflower biological yield increased significantly as a result of addition of chemical fertilizers and organic manure compared to control (**Table 2**). Maximum biological yield (3034 Kg·ha^{-1}) was produced by T_5. Data in (**Table 3**) showed that cultivar Leed-00 produced the maximum (3089 kg/ha) biological yield with the combination of FYM and half (N-P) fertilizers. However, cultivar Thori-78 produced maximum (2978 kg/ha) biological yield by treatment T_5 which was at par with T_4 and T_3. Maximum biological yields with integration of organic and inorganic fertilizers in safflower might be due to the increased availability of nutrients. Our results are in agreement with [24]. Moreover, [25] were of the opinion that balanced application of organic and inorganic fertilizer application has significant impact on stalk yield of safflower

3.6. Seed Yield (Kg/ha)

The maximum seed yield (435.7 Kg·ha^{-1}) was obtained by T_5, followed by T_3

(402.6 Kg·ha^{-1}) and T_4 (383.3 Kg·ha^{-1}), while, the minimum (319.8 Kg·ha^{-1}) seed yield was observed in T_1 (control). There were non-significant differences between the cultivars for seed yield. The overall performance of Leed-00 was better than Thori-78. The maximum (455.2 Kg·ha^{-1}) seed yield was observed in cultivar for Leed-00 by T_5 and maximum (416.2 Kg·ha^{-1}) seed yield was recorded in cultivar Thori-78 by T_5. Premier seed yield in tested cultivars of safflower might be due to more availability of nitrogen at vegetative growth stages as combination of inorganic source of nitrogen and farm yard manure [26] [27]. Flourished vegetative growth ultimately performed efficiently as stronger source and translocated more photosynthates resulting in higher seed yield. The results are in the agreement with [14] who concluded that integrated use of organic and inorganic fertilizer performed better over their sole application for the final seed yields of safflower. [28] also concluded that farm yard manure along with recommended dose of fertilizers significantly improved seed yield.

3.7. Correlation

Correlation coefficients among different pair of agronomic traits were calculated to find out relationship among various characters studied. The values of correlation coefficient are presented in (**Table 4**). It can be observed that seed yield plant^{-1} was positively correlated with plant height, number of heads plant^{-1}, number of seeds head^{-1} and 1000-grain weight that revealed importance of these characters in determining yield. Positive relationship between seed yield, plant height, number of heads plant^{-1} and number of seeds head^{-1} obtained in this study confirmed the findings of [29] [30]. The height positive correlation coefficient was determined between seed yield plant^{-1} and plant height (r = 0.890) and seed yield and number of head plant^{-1} (r = 0.868). These results are in accordance with the findings of [31] who observed highly positive correlation between seed yield per plant and head (capitulum) number.

3.8. Qualitative Characters

Figure 2 represents the significant differences for oil contents within the treatments and between the varieties Lead and Thori-78. Fatty acids contents like palmitic, stearic, oleic and linoleic acids are very decisive in determining the

Table 4. Correlation co-efficient for mean quantitative traits of safflower cultivars.

	PH	NOH	NOS	GW	BY
NOH	0.728143**				
NOS	0.78787**	0.824987**			
GW	0.792199**	0.843276**	0.711783**		
BY	0.612359*	0.841479**	0.644521*	0.767344**	
SY	0.890577**	0.868712**	0.835396**	0.808054**	0.706922**

* and ** significant at 0.05 level of significance. PH = Plant Height; GW = Grain Weight; NOH = No. of Heads Plant^{-1}; BY = Biological Yield; NOS = No. of Seeds Head^{-1}; SY = Seed Yield.

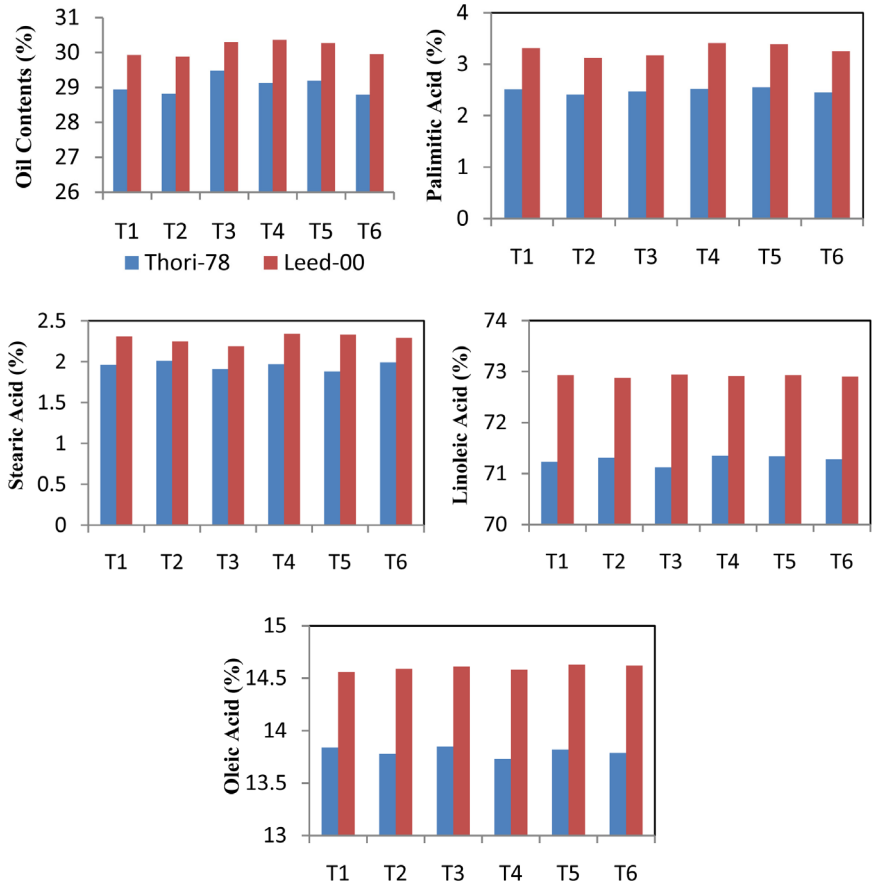

Figure 2. Effects of Integrated Nutrient Management (INM) treatments on oil yield, oil, palmitic, stearic, oleic and linoleic acids contents of safflower.

quality of oil in oil crops. No significant effect of integrated nutrient management was observed among all the treatments for fatty acid composition. Oil quality is a momentous concern of consumers, particularly for the contents of oleic and linoleic acids which are proven as health source of oil for humans. Saf-flower is considered to be one of the highest quality vegetable oils and consists of mainly palmitic, stearic, oleic and linoleic acids [32]. Significant difference of the contents of these fatty acids among tested safflower cultivars seems to be a genetic factor as there is no effect of integrated nutrient management was observed. [33] also stated that qualitative characters of a crop depend on seed related factors like genetic makeup.

4. Conclusion

The present study concluded that there is scope of increasing crop yields through use of integrated nutrient management. It is also important in maintaining soil fertility status. Exploitation of safflower as a useful nutritional, medicinal and industrial source may prove a key intervention to increase the popularity of this crop and for restoring its status as an important oilseed crop.

Novelty Statement

Exploring the potential of safflower and to include this high value crop in cropping pattern of Pakistan. Effective nutrient management not only maintains the fertility status of soil, also improve the economic yield.

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