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Effect of tillage and nutrient management practices on growth and yield of safflower after *kharif* rice

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Abstract
A field experiment was carried out during *rabi*, 2023 at College farm, College of Agriculture, Rajendranagar, Hyderabad, to study the effect of tillage and nutrient management practices on the growth and yield of safflower after *kharif* rice. The experiment was laid out in split plot design which was replicated thrice with two main plots and seven sub plots. Main plots included were *viz.*, M_1: Conventional tillage (Cultivator + Rotovator); M_2: Zero-tillage (sowing by dibbling). Sub plots included were N_1: 100% RDF (40-40-20 kg N-P_2O_5-K_2O ha^{-1}); N_2:100% RDF + Elemental Sulphur @ 20 kg ha^{-1}; N_3:100% RDF + Elemental Sulphur @ 40 kg ha^{-1}; N_4: 100% RDF + Elemental Sulphur @ 20 kg ha^{-1} + Zinc sulphate @ 20 kg ha$^{-1;}$ N_5:100% RDF + Elemental Sulphur @ 20 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}; N_6: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha$^{-1;}$ N_7: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}. The results revealed that among tillage methods conventional tillage has shown significantly higher plant height (84.3 cm), number of branches plant^{-1} (18.1), dry matter production (5195 kg ha^{-1}), number of capitula plant^{-1} (22.6), number of seeds capitulum^{-1} (23.4), seed yield (1845 kg ha^{-1}) and stalk yield (3959 kg ha^{-1}). Application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1} has resulted in higher plant height (95.1 cm), number of branches plant^{-1} (21.5), dry matter production (6112 kg ha^{-1}), number of capitula plant^{-1} (28.0), number of seeds capitulum^{-1} (27.2), grain yield (6467 kg ha^{-1}) and stalk yield (4547 kg ha^{-1}), and it is on par with 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}.

Keywords: Zinc sulphate, tillage, elemental sulphur, nutrient management

Introduction

India had achieved great strides in the production of food grains, but the low production level of oilseeds is a matter of great concern. The projected population of India are expected to be around 1.3 billion by 2025 AD and required oil seeds production will be around 102.3 mt by 2030 AD (DRMR, Vision 2030) [1]. Though India has achieved a breakthrough in production of food grains mainly through wheat and rice, it is yet to achieve self-sufficiency in the yield and production of oil seeds and pulses. Till now there is no major breakthrough to increase the production of vegetable oil through traditional crops. Oilseeds form the second-largest agricultural commodity after cereals in India. It accounts for 13% of Gross cropped area, 3% of GNP (Gross National Product) and about 10% of value of all the agricultural commodities (Directorate of oilseeds development, 2023) [2] owing to its vital role in the context of the sustainable economy of the country.

Safflower is a versatile crop and grown for its high-quality oil. It contains 11-24% protein and 24-36% oil in seed. Two kinds of unsaturated fatty acids are found in safflower oil *i.e.* linoleic acid (polyunsaturated fatty acids) and oleic acid (monounsaturated fatty acids). Linoleic acid aids in lowering blood cholesterol levels, and oleic acid is helpful in preventing coronary artery disease (Dajue and Mundel, 1996) [3]. Safflower oil is utilized in cooking because of its thermal stability. Natural colours are extracted from dried flower petals. Birds can be fed with the seeds of safflower oil cake, which is also a useful animal feed.

Globally, sustainable management of agricultural waste is a great challenge, especially in developing nations like India with a burgeoning population, production rate and economic growth (Govindasamy, 2008) [4]. India generates more than 500 million tonnes of crop residues annually. Burning of crop residues causes air pollution and lead to loss of soil biota, huge biomass, organic carbon and plant nutrients. In present scenario due to fast declining natural resources (soil, water and energy) and increasing cost of production and environmental problems, conservation agriculture (CA) based crop production technologies are gaining much attention to explore maximum yield potential of *rabi* crops.

Safflower can be grown successfully in various types of soils like vertisols, alfisols and oxisols. Sulphur helps in increasing the oil content of oilseed crops and also in determining the quality of the oil. Sulphur plays an important role for the formation of sulphur containing amino acids and oil synthesis (Gangadhara *et al.* 1990) [5]. It is a part of coenzyme A, pyrophosphates, vitamins such as biotin and thiamine. Higher yield and maximum oil quality can only be ensured when all the three major nutrients like nitrogen, phosphorus and potassium along with suitable doses of sulphur as well as micronutrients like zinc can be applied in a balanced way (Khoshgoftarmanesh *et al.*, 2010) [6]. In secondary and micronutrient nutrition apart from determining the response, identification of right source and dose is also very essential for optimizing production.

Zinc deficiency is the most common widespread micronutrient deficiency. It plays a very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome. As a structural, functional, or regulatory cofactor of numerous enzymes, zinc is recognized to play a significant role. Plant water intake and transport capacities are affected, and the negative consequences of brief exposure to heat and salt stress are lessened.

Therefore, looking into paucity of research data, a study was undertaken to find out the "Effect of tillage and nutrient management options on performance of safflower after *kharif* rice"

Materials and Methods

The field experiment was carried out at College Farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana Agricultural University, Hyderabad. The farm is located at an altitude of 542.5 meters above mean sea level, and 17° 32' 18" N latitude and 78° 41' 31" E longitude. The experimental plot comes under Southern Agro-Climatic Zone of Telangana. According to Troll's classification, it falls under S.Emi-arid tropics (SAT).

The experiment was carried out on clay loamy soils which was low in organic carbon, and with pH slightly alkaline in nature, low in available nitrogen, medium in available phosphorous, high in available potassium and low in available sulphur. The test variety selected was ISF 764 developed by ICAR-Indian Institute of Oilseeds Research, Hyderabad, matures in 125–130 days. The seed rate used was 10 kg ha^{-1} and two seeds per hill were dibbled at a spacing of 45 cm x 20 cm.

The experiment was laid out in a split plot design with two main plots pertaining to tillage methods M_1: Conventional tillage (Cultivator + Rotovator); M_2: Zero-tillage (sowing by dibbling/seed drill) and seven sub plots pertaining to nutrient levels N_1: 100% RDF (40-40-20 kg N-P_2O_5-K_2O ha^{-1}); N_2:100% RDF + Elemental Sulphur @ 20 kg ha^{-1}; N_3:100% RDF + Elemental Sulphur @ 40 kg ha^{-1}; N_4: 100% RDF + Elemental Sulphur @ 20 kg ha^{-1} + Zinc sulphate @ 20 kg ha$^{-1;}$ N_5:100% RDF + Elemental Sulphur @ 20 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}; N_6: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}; N_7: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1} and was replicated thrice. The recommended dose of nitrogen, phosphorus and potassium were applied to all the plots @ 40:40:20:kg N, P_2O_5 and K_2O ha^{-1} and for specific treatments Sulphur and Zinc were applied in the form of elemental sulphur and zinc sulphate respectively as basal at the time of sowing. Entire dose of P_2O_5 and K_2O were applied as basal. Nitrogen was applied in two split doses. First dose was applied at the time of sowing and second dose was applied at 40 DAS. Pre-emergence herbicide, pendimethalin @ 0.75 kg a.i. ha^{-1} was applied on the 2nd day after sowing. Throughout the safflower growing season, all other agronomic practices were applied uniformly across the experimental units.

Results and Discussion

Plant height at harvest (cm)

Plant height is a simple yet effective indicator of a plant's growth and vigor. Among main plots the conventional tillage has shown significantly highest plant height (84.3 cm) than Zero-tillage (81.2 cm) at harvest. Among sub plots highest plant height of 95.1 cm was registered under N_7 treatment (100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}) and was found on par with N_6 (100% RDF + Elemental sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}) (92 cm). Significantly lowest plant height at harvest was registered under N_1 (100% RDF (40-40-20 kg N-P_2O_5-K_2O ha^{-1}) (66.8 cm). Among tillage systems conventional tillage has recorded highest plant height than zero tillage. Tillage helps to improve soil physical condition resulting in vigorous root growth of crops which aids in increasing plant height by utilising the moisture available at lower soil regions. Similar results were reported by Singh and Verma (1995) [7]. Application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1} have resulted in highest plant height. Increase in plant height with the increasing fertility levels might be due to higher nutrient supply, rapid conversion of carbohydrates in to protein which in turn elaborated into protoplasm. Similar findings were reported by Kushwaha *et al.* (2017) [8], Pandey and Chauhan (2016) [9].

The interaction effect due to tillage practices and nutrient levels on plant height was found non significant at all the crop growth stages.

Number of branches plant^{-1}

Safflower produced highest number of branches plant^{-1} with conventional tillage (18.1) which was significantly superior to zero tillage treatment (16.8) at harvest. Among sub plot treatments application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}) (21.5) has showed significantly highest number of branches plant^{-1} at harvest and was found at par with treatment N_6 (100% RDF + Elemental sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}) (20.7). Increase in number of branches might be due to increase in cell multiplication, cell elongation and cell expansion throughout the entire period of crop. This might be ascribed to adequate supply of sulphur that resulted in higher production of photosynthates and their translocation to sink, which ultimately increased the plant growth and growth attributes (Satish Kumar *et al.*, 2011) [10]. These are in line with findings of Ravi *et al.* (2010) [11].

The interaction effect due to tillage and nutrient management practices on number of branches plant^{-1} was found to be non significant at all the crop growth stages.

Dry matter production (kg ha^{-1})

Among main plots safflower produced higher dry matter with conventional tillage (5195 kg ha^{-1}) which was significantly superior over zero tillage treatment (4944 kg ha^{-1}) at harvest. Among sub plot treatments application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1} (6112 kg ha^{-1}) has resulted in highest dry matter production at harvest and was found at par with 100% RDF + Elemental sulphur @ 40 kg ha + Zinc sulphate @ 20 kg ha^{-1} (5844 kg ha^{-1}) application.

The interaction effect due to tillage and nutrient management practices on dry matter production was found to be non significant at all the crop growth stages.

Conventional tillage had shown more dry matter accumulation, it might be due to favorable soil conditions, *i.e.*, tillage and high available moisture capacity created with tractor drawn cultivator and rotavator that resulted in better crop growth and enhanced high dry matter accumulation. Similar findings were observed by Gurumurthy *et al*. (2008) [12]

Application of sulphur might have influenced the overall nutritional environment of rhizosphere. The sulphur being a constituent of succinyl Co-A involved in chlorophyll synthesis in plant leaves and their activation at cellular level by promoting photosynthates and meristamatic activity which has promoted increase in plant height and number of branches. Also proper partitioning of photosynthates from source to sink and there by incresed the drymatter production. Similar results were reported by Poomurugesan and Poonkodi (2008) [13].

Yield attributes and yield

Number of capitula plant^{-1}

Significantly higher number of capitula plant^{-1} were registered under conventional tillage (22.6) as compared to zero tillage (21.3). Similar findings were reported by Atluntas *et al.* (2018) [14].

Application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}) (28) has produced highest number of capitulum plant^{-1} which was statistically on par with 100% RDF + Elemental sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}) (26.9). This might be because of better growth of plant due to availability of sulphur leading to increased number of capsules plant^{-1} as seed yield is directly related to the growth and yield attributes (Patil *et al*., 2014) [15]. The results of the present study are in line with that of Singh and Singh (2013) [16].

The interaction effect due to tillage and nutrient management practices in safflower on number of capitulum plant^{-1} was found to be non significant

Table 1: Growth parameters of safflower as influenced by tillage and nutrient management practices after *kharif* rice.

Treatments	Plant height (cm)	Number of branches plant^{-1}	Dry matter production (kg ha^{-1})
Main plot treatments			
M_1: Conventional tillage (Cultivator + Rotovator)	84.3	18.1	5195
M_2: Zero-tillage (sowing by dibbling)	81.2	16.8	4944
S.Em±	0.50	0.18	39.48
CD (P=0.05)	3.04	1.11	240.25
Sub plot treatments			
N_1: 100% RDF (40-40-20 kg N-P_2O_5-K_2O ha^{-1})	66.8	12.1	3839
N_2: 100% RDF + Elemental Sulphur @ 20 kg ha^{-1}	74.8	14.2	4259
N_3: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1}	78.1	16.1	4638
N_4: 100% RDF + Elemental Sulphur @ 20 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}	84.6	17.5	5161
N_5:100% RDF + Elemental Sulphur @ 20 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}	88.0	20.0	5634
N_6: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}	92.0	20.7	5844
N_7: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}	95.1	21.5	6112
S.Em±	1.19	0.40	103.17
CD (P=0.05)	3.47	1.15	301.13
Interaction			
Sub treatment at same level of main treatment			
S.Em±	1.68	0.56	145.91
CD (P=0.05)	NS	NS	NS
Main treatment at same/different level of sub treatment			
S.Em±	1.63	0.55	140.73
CD (P=0.05)	NS	NS	NS

Number of seeds capitulum^{-1}

Significantly higher number of seeds capitula^{-1} were registered under conventional tillage (23.4) as compared to zero tillage (22.3). Application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1} (27.2) had produced highest number of capitulum plant^{-1} which was statistically similar to treatment N_6 (100% RDF + Elemental sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}) (26.0). The higher nutrient levels had resulted in larger capitula which accomodated more number of seeds. The results are in conformity to that of Chauhan *et al.* (2001) [17].

However the interaction effect due to tillage and nutrient management practices in safflower on number of seeds capitulum^{-1} was found to be non significant.

Seed yield (kg ha^{-1})

Significantly higher seed yield was observed under conventional tillage (1845) over zero tillage (1720). Application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1} had produced significantly higher seed yield of 2151 kg ha^{-1} but was found on par with N_6 treatment (100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}) (2027). Significantly lowest seed yield of 1332 kg ha^{-1} was observed with 100% RDF (40-40-20 kg N-P_2O_5-K_2O ha^{-1}). It is observed that increase in seed yield in conventional tillage might be due to increase in growth and yield attributes like dry matter accumulation, number of capitula plant^{-1}, number of seeds capitula^{-1}. Similar results of increase in yield under tilled conditions were reported by Sree *et al.* (2006) [18]. Increased seed yield is directly a function a yield attributing characters like number of capitula plant^{-1}, number of seeds capitula plant^{-1} as observed in present study. Sulphur increased the seed yield by aiding in formation of structural proteins. Also due to more accumulation of amino acids and amide substances and their translocation to reproductive organ, which influenced growth and yield due to sulphur application. Similar findings were reported by Ravi *et al*. (2008) [19]. The increase in yield might also be due to role of zinc in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthates towards them, which resulted in better flowering and fruiting. The findings of present investigation are supported by Upadhyay (2012) [20].

The interaction effect due to tillage and nutrient management practices was found to be non significant on seed yield of safflower.

Stalk yield (kg ha^{-1})

Significantly higher stalk yield was observed under conventional tillage (3959 kg ha^{-1}) over zero tillage (3748 kg ha^{-1}). The more root growth and it could be inferred from the plant characters like plant height, number of branches, and total dry matter which influenced the biological yield. Among sub plot treatments application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1} has produced higher seed yield of 4547 kg ha^{-1} was found on par with N_6 treatment (100% RDF + Elemental sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}) (4503). Significantly lowest stalk yield of 2985 kg ha^{-1} was observed with 100% RDF (40-40-20 kg N-P_2O_5-K_2O ha^{-1}). Similar results were reported by Sahay *et al*. (2009) [21] and Singh *et al*. (2014) [22]. The interaction effect due to tillage and nutrient management practices was found to be non significant on stalk yield of safflower

Table 2: Yield attributes and yield of safflower as influenced by tillage and nutrient management practices after *kharif* rice.

Treatments	No. of capitula plant^{-1}	No. of seeds capitulum^{-1}	Seed yield	Stalk yield
Main plot treatments				
M_1: Conventional tillage (Cultivator + Rotovator)	22.6	23.4	1845	3959
M_2: Zero-tillage (sowing by dibbling)	21.3	22.3	1720	3748
S.Em±	0.20	0.18	19.09	27.20
CD (P=0.05)	1.22	1.09	116.15	165.48
Sub plot treatments				
N_1: 100% RDF (40-40-20 kg N-P_2O_5-K_2O ha^{-1})	15.2	17.7	1332	2985
N_2: 100% RDF + Elemental Sulphur @ 20 kg ha^{-1}	17.3	19.7	1498	3230
N_3: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1}	19.3	21.4	1661	3535
N_4: 100% RDF + Elemental Sulphur @ 20 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}	21.8	22.9	1811	3856
N_5:100% RDF + Elemental Sulphur @ 20 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}	25.3	24.9	1998	4307
N_6: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 20 kg ha^{-1}	26.9	26.0	2027	4503
N_7: 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1}	28.0	27.2	2151	4547
S.Em±	0.63	0.48	46.53	80.32
CD (P=0.05)	1.84	1.39	135.82	234.43
Interaction				
Sub treatment at same level of main treatment				
S.Em±	0.89	0.67	65.81	113.59
CD (P=0.05)	NS	NS	NS	NS
Main treatment at same/different level of sub treatment				
S.Em±	0.85	0.65	63.85	108.62
CD (P=0.05)	NS	NS	NS	NS

Conclusion

On the basis of experimental findings, it can be concluded that conventional tillage was found to be best for higher crop growth and yield of safflower after *kharif* rice. Application of 100% RDF + Elemental Sulphur @ 40 kg ha^{-1} + Zinc sulphate @ 40 kg ha^{-1} can be recommended for safflower as it had shown increased growth parameters and yield.

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