Original Research Article

Effect of Rice Straw Mulching and Irrigation Regimes on Yield and Yield Attributes of Sunflower (*Helianthus annuus* L.) in Rice Fallow

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ABSTRACT

A field experiment was conducted at Agriculture Research Institute, PJTSAU, Hyderabad during *rabi*(December to March), 2021–22 to study the performance of zero tillage sunflower (*Helianthus annuus* L.) under different levels of rice straw mulching and irrigation regimes in rice fallows. The farm is geographically situated at 17º 3' N latitude, 78º 39' E longitude and at an altitude of 494 m above mean sea level. The treatments were laid out in Factorial randomized block design in three replications with eight treatment combinations. Mulch treatments were two (M_1–1.5 t ha^{-1} rice straw and M_2–7.5 t ha^{-1} rice straw) and irrigation treatments were four (I_1–IW/CPE=0.8, I_2–IW/CPE=1.0, I_3–IW/CPE=1.2 and I_4–scheduling irrigation at critical stages) were allocated to different plots. The results revealed that capitulum diameter (14.3 cm), Number of filled seeds per capitulum (1225), Weight of filled seeds per capitulum (43.5 g), 100 seed weight (4.58 g) and seed yield (2216 kg ha^{-1}) of sunflower was significantly higher under M_2 (mulching with 7.5 t ha^{-1} rice straw) treatment than that of under M_1 (mulching with 1.5 tha^{-1} rice straw). The results also indicated that among irrigation treatments, the capitulum diameter (14.2 cm), No. of filled seeds per capitulum (1310), Weight of filled seeds per capitulum (45.2 g), 100 seed weight (4.62 g) and seed yield (2361 kg ha^{-1}) of sunflower was significantly higher under I_3–IW/CPE=1.2 treatment than that of under other irrigation treatments under study.

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Keywords: Sunflower, organic mulching, irrigation, zero tillage, rice fallow

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an important oilseed crop in India popularly known as "Surajmukhi". Sunflower belongs to the family Asteraceae and genus Helianthus which contains 65 different species Andrew et al.[2]. It is known as sunflower as it follows the sun by day, always turning towards its direct rays. In India, sunflower crop was introduced in 1969, prior to which it was used mainly as an ornamental plant. Sunflower is a wonder crop due to its special features like short duration, drought resistance, thermo and photo insensitivity, higher water use efficiency and low seed requirement Kadasidappaet al.[9].It's high oil content ranges between 40–52% which is considered as premium oil because of its light colour, high level of unsaturated fatty acids, lack of linoleic acid, bland flavour and high smoke points. It is also good for human consumption because of its anti-cholesterol properties Brar

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et al.[6]. Presently sunflower ranks next to soybean, groundnut and mustard in the total world production of oilseed Kumar et al.[11].

Sunflower is an important oil seed crop gaining paramount importance in the world and ranks next only to soybean and groundnut in the total world production of oil seedsTomar et al.[17], Zhao et al.[2]. Sunflower is one of the most important oil seed crops of India. It is being cultivated over an area of about 2.28 lakh hectares with a production of 2.13 lakh tonnes and productivity of 931 kg ha^{-1} Anonymous. [4].The important sunflower growing states are Karnataka, Maharashtra, Odisha, Haryana and Andhra Pradesh and almost 50 % of the area and production is contributed alone by Karnataka. In Telangana, sunflower is being grown in an area of 4046 hectares, producing 8000 tonnes with the productivity of 1698 kg ha^{-1}Anonymous. [3]. Conservation agriculture (CA) has been developed in conventional farming to minimize and prevent soil erosion, reduce labour and energy inputs, and preserve soil fertility. The no–till system is a specialized type of conservation tillage consisting of aonepass planting and fertilizer operation in which the soil and the surface residues are minimally disturbed. The surface residues of such system are of critical importance for soil and water conservation Selvakumar et al.[15].

The conservation of soil moisture through mulching is one of the important purposes. The micro–climatic conditions are favourably affected by optimum degree of soil moisture. When soil surface is covered with mulch helps to prevent weed growth, reduce evaporation and increase infiltration of rain water during growing season. It provides many benefits to crop production through soil and water conservation. Mulching with different materials has been demonstrated to reduce water evaporation (Li et al., 2013; Pabin et al., 2003), improve fallow efficiency and increase the amount of stored soil water available for plant use (Wang et al., 2001).Organic mulches (wheat or paddy straw, plant leaves, compost, rice hulls, and sawdust, etc) can decompose naturally when used as mulch and increase the water holding capacity of soil and also provide the nutrients during course of break down (Thakur et al.[16]; Atreya et al.[5]. Rice straw mulch is an organic biodegradable material that is suitable for use as a mulch(Kader et al.[10].

Optimum irrigation scheduling is one of the most important production management practices for increased water use efficiency in irrigated sunflower. This research was aimed to evaluate the effects of irrigation and straw mulch on seed yield of sunflower in rice fallows during *rabi* season.

2. MATERIALS AND METHODS

A field experiment was conducted at Agriculture Research Institute, PJTSAU, Rajendranagar, Hyderabad during *rabi*season, 2021–22. The farm is geographically situated at 17º 3' N latitude, 78º 39' E longitude and at an altitude of 494 m above mean sea level (MSL) and falls under the Southern Telangana agro–climatic zone of Telangana. According to Troll's climate classification, it falls under semi–arid tropic region (SAT). The soil of experimental site was clay loam in texture and slightly alkaline in reaction (pH 7.8). The soil was low in available nitrogen (181 kg ha^{-1}) and medium in phosphorus (33 kg ha^{-1}) and high in available potassium (313 kg ha^{-1}). The treatments were laid out in Factorial

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randomized block design (FRBD) in three replications with eight treatments. Mulch treatments (M_1–1.5 t ha^{-1} rice straw and M_2–7.5 t ha^{-1} rice straw) and irrigation treatments (I_1-IW/CPE=0.8, I_2-IW/CPE=1.0, I_3-IW/CPE=1.2 and I_4–scheduling irrigation at critical stages) were allocated to different plots.

The treatments were imposed at 10 days after sowing. The rice straw @ 1.5 and 7.5 t ha^{-1} were mulched at 10 days after sowing as per the treatments. These were spread uniformly in between the sunflower crop rows. Irrigation schedules were decided on the basis of cumulative pan evaporation (CPE), which was obtained by recording the open pan evaporimeter reading every day. Cumulative pan evaporation was taken as sum of daily evaporation minus rainfall from the date of previous irrigation and this process was repeated. 50 mm depth of water was provided at every irrigation through surface flooding method. Five plants were randomly selected from net plot area and tagged for recording various observations. The yield and the yield attributes were recorded at harvest adopting standard procedure, and data on various parameters were subjected to statistical analysis to draw the interpretation of the data Gomez and Gomez.[8].

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3. Results and Discussion

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The experimental data of yield attributes of sunflower under different levels of mulching and irrigation was analyzed statistically and it was found that the yield attributes i.e., capitulum diameter, number of filled seeds per capitulum, filled seed weight per capitulum and 100 seed weight was significantly influenced by different levels of mulching and irrigation. The detailed results were mentioned below.

3.1. Capitulum diameter (cm)

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Perusal of the data (Table 1) indicated that, capitulum diameter of sunflower was significantly influenced by the levels of straw mulching and irrigation. Among mulching levels, capitulum diameter (14.3 cm) was significantly higher under M_2 (mulching with 7.5 t ha^{-1} rice straw) treatment than that of under M_1 (mulching with 1.5 t ha^{-1} rice straw) treatment (13.4 cm). This increase in the capitulum diameter under higher level of mulching i.e., under M_2 treatment may be attributed to the higher availability of soil moisture and also to the slower rate of depletion of soil moisture due to mulching in that treatment and the similar findings were also reported by Paul et al. [13].

The capitulum diameter of sunflower under I_3(IW/CPE=1.2) irrigation level (14.2 cm) was significantly higher than that of under I_1 (IW/CPE=0.8) (13.7 cm), I_2 (IW/CPE=1.0) (13.7 cm) and I_4 (irrigation at critical stages of crop growth) (13.4 cm) irrigation levels. It was also noticedthat the capitulum diameter under I_1 (IW/CPE=0.8) (13.7 cm), I_2 (IW/CPE=1.0) (13.7 cm) and I_4 (irrigation at critical stages of crop growth) (13.4 cm) irrigation levels was on par with each other. This increase in the capitulum diameter under I_3 irrigation level might be linked to the combined effect of application of higher amount of irrigation water by more number of irrigations under that treatment than the rest of the treatments. This also contributed to the more vigorous and luxuriant vegetative growth in turn favoured better partitioning of assimilates from source to sink. These results were in conformity with Alipatra et al.[1].The interaction effect of different levels of straw mulch and irrigation regimes on capitulum diameter of sunflower was non-significant.

3.2. Number of filled seeds per capitulum

Analysis of data (Table 1) revealed that, number of filled seeds per capitulumin sunflower was significantly influenced by the levels of straw mulching and irrigation. The number of filled seeds per capitulum under M_2 (mulching with 7.5 t ha^{-1} rice straw) (1143) treatment was significantly higher than that of under M_1 (mulching with 1.5 t ha^{-1} rice straw) treatment (1225). Higher number of filled seeds per capitulumin sunflower under M_2 treatment might be ascribed to the to the higher availability of soil moisture and also to the slower rate of depletion of soil moisture due to mulching in that treatment and also to the higher capitulum diameter in that treatment. Similar findings were also reported by Paul et al.([13].

Number of filled seeds per capitulumin sunflower under I_3 (IW/CPE=1.2) irrigation level (1310) was significantly higher than that of under I_1 (IW/CPE=0.8) (1109) and I_4 (irrigation at critical stages of crop growth) (1092) irrigation levels but on par with that of under I_2 (IW/CPE=1.0) (1226) irrigation level. Further, the number of filled seeds per capitulum under I_1 (IW/CPE=0.8) (1109) and I_4 (irrigation at critical stages of crop growth) (1092) irrigation levels was on par with each other. Higher number of filled seeds per capitulumin sunflower under I_3 irrigation level might be associated to the combined effect of application of higher amount of irrigation water by more number of irrigations under that treatment than the rest of the treatments and thus contributed to the more vigorous and luxuriant vegetative growth in turn higher capitulum size and number of filled seed per capitulum due to better partitioning of assimilates from source to sink. These results were in conformity with Alipatraet al. [1]. The interaction effect of different levels of straw mulch and irrigation regimes on number of filled seeds per capitulum of sunflower was found non–significant.

3.3. Weight of filled seeds per capitulum (g)

The data (Table 1) revealed that, weight of filled seeds per capitulumin sunflower was significantly influenced by the levels of straw mulching and irrigation. Results indicated the filled seed weight per capitulum (43.5 g) recorded under M_2 (mulching with 7.5 t ha^{-1} rice straw) treatment was significantly higher than that under M_1 (mulching with 1.5 t ha^{-1} rice straw) treatment (40.8 g). Higher filled seed weight per capitulum under higher level of mulching i.e., M_2 (mulching with 7.5 t ha^{-1} rice straw) treatmentmight be due to the to the higher availability of soil moisture and also to the slower rate of depletion of soil moisture which in turn improved translocation of photosynthates towards the developing capitulum. Similar findings were reported by Raghupatiet al.[14].

Further, sunflower crop under I_3–IW/CPE=1.2 treatment recorded significantly higher filled seed weight per capitulum(45.2 g)than under I_1–IW/CPE=0.8 (40.4 g), I_2–IW/CPE=1.0 (41.6 g) and I_4 (critical stages) (39.2 g) irrigation treatments. This escalation of filled seed weight under I_3–IW/CPE=1.2 treatment was likely due to higher 100 seed weight under that treatment and the results were in agreement withRaghupatiet al.[14]. However, the interaction effect of different levels of straw mulch and irrigation regimes on filled seed weight per capitulum was non–significant.

3.4. 100 Seed weight

100 seed weight was significantly influenced by the levels of straw mulching and irrigation(Table 1). Significantly higher 100 seed weight of sunflower was recorded under M_2 (mulching with 7.5 t ha^{-1} rice straw) treatment (4.58 g) than that under M_1 (mulching with 1.5 t ha^{-1} rice straw) treatment (4.33 g). Higher 100 seed weightin sunflower under M_2 treatment might be due to the to the higher availability of soil moisture and also to the slower rate of depletion of soil moisture due to mulching in that treatment which in turn improved translocation of photosynthates towards the developing the seed. Similar results were reported byZhao et al.[19].

100 seed weight of sunflower under I_3 (IW/CPE=1.2) irrigation level (4.62 g) was significantly higher than that of under I_1 (IW/CPE=0.8) (4.40 g), I_2 (IW/CPE=1.0) (4.43 g) and I_4 (irrigation at critical stages of crop growth) (4.29) irrigation levels. It was also noticedthat the 100 seed weight of sunflower under I_1 (IW/CPE=0.8) (4.40 g), I_2 (IW/CPE=1.0) (4.43 g) and I_4 (irrigation at critical stages of crop growth) (4.29 g) irrigation levels was on par with each other. This gain in the 100 seed weight under I_3 irrigation level might be linked to the combined effect of application of higher amount of irrigation water by more number of irrigations under that treatment than the rest of the treatments. This also contributed to the more vigorous and luxuriant vegetative growth in turn favoured better partitioning of assimilates from source to sink. These results were in conformity withAlipatra et al.[1].

The interaction effect of different levels of straw mulch and irrigation regimes on 100 seed weight of sunflower was found non–significant.

3.5. Seed yield (kg ha^{-1})

Perusal of the data (Table 2) indicated that the seed yield of sunflower was significantly influenced by different levels of straw mulching and irrigation levels. Seed yield under M_2 (mulching with 7.5 t ha^{-1} rice straw) (2216 kg ha^{-1}) was significantly higher than the seed yield under M_1 (mulching with 1.5 t ha^{-1} rice straw) (1951 kg ha^{-1}) treatment. Higher seed yieldin sunflower under M_2 treatment might be attributedto the higher availability of soil moisture and also to the slower rate of depletion of soil moisture due to soil moisture conservation through mulching in that treatment. This facilitated a better crop growth and development and also improved translocation of photosynthates towards the developing the seed. These results were in accordance with Paul et al. [13].

A scrutiny of the data revealed that the highest seed yield was obtained under I_3–IW/CPE=1.2 treatment (2361 kg ha^{-1}), which was significantly higher than the seed yield under I_2–IW/CPE=1.0 (2171 kg ha^{-1}), I_1–IW/CPE=0.8 (1967 kg ha^{-1}) and I_4 (irrigation at critical stages of crop growth) (1835 kg ha^{-1}). Lowest seed yield was recorded under I_4 (irrigation at critical stages of crop growth) (1835 kg ha^{-1}). The higher seed yield under I_3–IW/CPE=1.2 treatment might be ascribed to the combined effect of application of higher amount of irrigation water by more number of irrigations under that treatment than the rest of the treatments. This also contributed to the favourable influence on the growth parameters (plant height and dry matter production) and yield attributing characters (head diameter, number of seeds per capitulum and 100 seed weight). Similar findings were reported byElnaz et al. [7].

Further, the interaction effect of different levels of straw mulch and irrigation regimes on seed yield of sunflower was found non–significant.

4. Conclusion

It was concluded that yield and yield attributes of sunflower significantly influenced by different levels of straw mulching and irrigation regimes. Further, it was concluded that growing of zero tillage sunflower crop with 7.5 tonne ha^{-1} rice straw mulch and irrigation scheduling at IW/CPE=1.2 gave higher yield over the other treatments.

7. Reference

Comment [sj27]: Please recheck to ensure all the citations are reflected in the reference and vice versa

1. Alipatra A, Banerjee H, Bhattacharyya K, Bandopadhyay P, Mazumdar D, Sarkar S. Productivity, nutrient uptake and profitability of hybrid sunflower (Helianthus annuus L.) as influenced by irrigation and fertilizer–management practices under sub–tropical climate of West Bengal. Indian Journal of Agronomy, 2019;64(1):107–114.
2. Andrew RL, Kane NC, Baute GJ, Grassa CJ,Rieseberg LH. 2013. Recent nonhybrid origin of sunflower ecotypes in a novel habitat. Molecular Ecology, 2013;22(3): 799–813.
3. Anonymous, 2019.Department of Economics and Statistics, 2019-20. Telangana open data portal. Available from https://data.telangana.gov.in. Accessed on 5th July, 2022.
4. Anonymous, 2020.Ministry of Agriculture and Farmers Welfare, Govt. of India (2019–2020). Available from https://www.indiastat.com/data/agriculture/sunflower/data-year/2020. Accessed on 5th July, 2022.
5. Atreya K, Sharma S, Bajracharya RM, Rajbhandari NP. Developing a sustainable agro-system for central Nepal using reduced tillage and straw mulching. Journal of Environmental Management,2008;88: 547-555.
6. Brar JS, Mahal SS, Saini KS, Brar NS. Response of sunflower yield to planting methods and irrigation schedules. Indian Journal of Agricultural Research, 2016; 50(1): 71-75.
7. Elnaz E, Seyyed MS, Ahmad B, Christos AD. Seed yield and oil quality of sunflower, safflower, and sesame under different levels of irrigation water availability. Agricultural Water Management,2019;218: 149-157

8. Gomez KA, GomezAA, Statistical procedures for agricultural research (2 ed.). John wiley and sons, New York, 1984, (680).

9. Kadasidappa MM, Rao VP, Yella Reddy K, Ramulu V, Uma DeviM, Narender RS. Effect of irrigation (drip/surface) on sunflower growth, seed and oil yield, nutrient uptake and water use efficiency. Agricultural Reviews, 2017;38(2): 152-58.

10. Kader MA, Senge M,Mojid MA, Ito K. Recent advances in mulching materials and methods for modifying soil environment,Soil and Tillage Research,2017;168: 155-166.

11. Kumar T, Haque MA, Islam MS, Hoque MF, Jodder R. Effect of polythene mulch on growth and yield of Sunflower (Helianthus annuus). Archives Crop Science, 2018;2(1): 38-46.Li S, Wang Z, Li S, Gao Y, Tian X. Effect of plastic sheet mulch, wheat straw mulch, and maize growth on water loss by evaporation in dryland areas of China. Agricultural Water Management, Elsevier,2013;116 (C): 39-49.

12. Pabin J, Lipiec J, Wlodek S, Biskupski A. Effect of different tillage systems and straw management on some physical properties of soil and on the yield of winter rye in monoculture. International Agrophysics, 2003;17: 175-181.

13. Paul PLC, Bell RW, Barrett–Lennard, EG, Kabir E. Straw mulch and irrigation affect solute potential and sunflower yield in a heavy textured soil in the Ganges Delta. Agricultural Water Management, 2020;239: 1-10.

14. Raghupati D, Channagouda RF, Kamble AS, Janwade AD,Nekar M. Influence of irrigation schedules and mulches on growth and quality of sunflower (Helianthus annuus L.) in black soil of Northern Transitional Tract of Karnataka. International Journal of Agricultural Sciences, 2010;6(1): 120–123.

15. Selvakumar S, Sivakumar K. Conservation Agriculture: A Way for Soil Water Conservation. Agricultural Reviews, 2021; 42(4): 474-477.

16. Thakur M, Kumar R. Mulching–Boosting crop productivity and improving soil environment in herbal plants. Journal of Applied Research on Medicinal and Aromatic Plants, 2021;20:100-287.

17. Tomar SS, Shivran AC, Dungarawal HS. Influence of irrigation scheduling on yield, consumptive use of water, water use efficiency and economics of rabi sunflower (Helianthus annuus L.). Annals of Agricultural SciencesNews Series, 2003;24: 432-433.

18. Wang S, Liu P, Liu D, Lu S. Plastic film covering is the key measure for high yield of corn in terraced land in north Shaanxi. Agricultural Research in the Arid Areas, 2001;19: 20-25.

19. Zhao Y, Li Y, Wang J. Buried straw layer plus plastic mulching reduces soil salinity and increases sunflower yield in saline soils. Soil Tillage Research,2016;155: 363-370.

Comment [sj28]: What is happening here?

Treatment	Capitulum diameter (cm)	No. of filled seeds per capitulum	Weight of filled seeds per capitulum (g)	100 seed weight (g)

Factor 1: Mulching levels				
M_1	13.4	1143	40.8	4.33
M_2	14.3	1225	43.5	4.58
SEm ±	0.1	27	0.8	0.04
CD (P=0.05)	0.3	82	2.4	0.13
Factor 2: Irrigation regimes				
I_1 - IW/CPE=0.8	13.7	1109	40.4	4.40
I_2 - IW/CPE=1.0	13.7	1226	41.6	4.43
I_3 - IW/CPE=1.2	14.2	1310	45.2	4.62
I_4- Critical stages	13.4	1092	39.2	4.29
SEm ±	0.1	38	1.1	0.06
CD (P=0.05)	0.4	116	3.4	0.18
Interaction (M x I)				
SEm ±	0.2	53	1.6	0.09
CD (P=0.05)	NS	NS	NS	NS

Tables 1: Capitulum diameter, No. of filled seeds per capitulum, Weight of filled seeds per capitulum and 100 seed weight of sunflower as influenced by different levels of organic mulching and irrigation regimes

Table 2 :SeedYield (kg ha^{-1}) of sunflower as influenced by different levels of organic mulching and irrigation regimes

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Treatments	Seed yield (kg ha^{-1})				
	I_1 - IW/CPE=0.8	I_2 - IW/CPE=1.0	I_3 - IW/CPE=1.2	I_4- Critical stages	Mean
M1	1867	2002	2175	1759	1951
M2	2067	2340	2546	1910	2216
Mean	1967	2171	2361	1835	
	M	**I**	**M × I**		
SEm±	25	**35**	**50**		
C.D (P=0.05)	**76**	**108**	**NS**		

Figures:

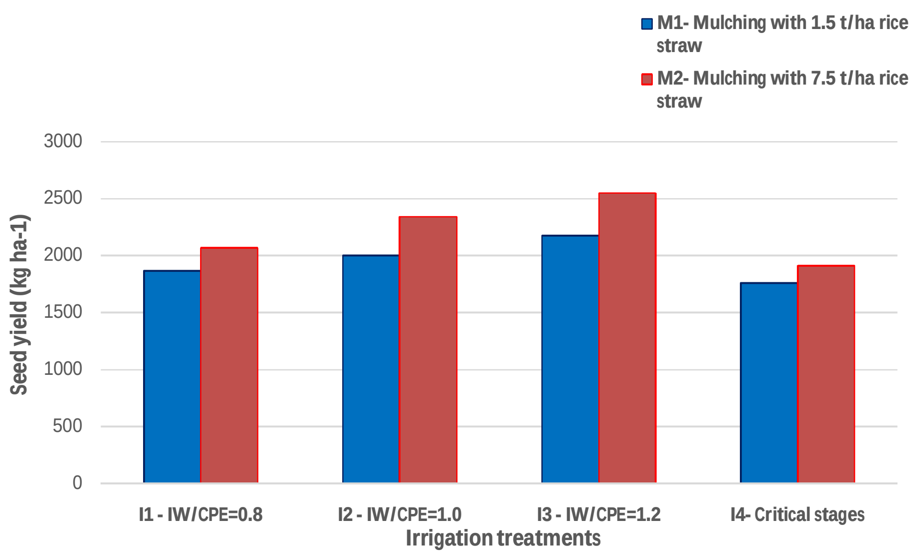

fig.1 Seed yield (kg ha^{-1}) of sunflower as influenced by different levels of organic mulching and irrigation regimes

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