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INFLUENCE OF TILLAGE PRACTICES ON CHEMICAL PROPERTIES OF SOIL AND ON UPTAKE AND DRY MATTER PRODUCTION BY PULSE CROPS GROWN IN RICE FALLOWS

Sk. Afzal[1*], M. Madhu[2], A.V. Ramanjaneyulu[3] and Ch. Ramulu[4]
[1]College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad –500030, Telangana, India.
[2]AICRP on Pigeon pea, RARS Warangal-506007, Telangana, India
[3]AICRP on Agroforestry, Rajendranagar, Hyderabad,Telangana, India
[4]Regional Agricultural Research Station (RARS), Warangal-506007, Telangana, India.
*Corresponding author E-mail: afzalajjusk@gmail.com
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ABSTRACT

A research study was conducted during the *rabi* season of 2022-23 at research farm in Siddapur, Regional Agricultural Research Station (RARS), Warangal, Telangana, India to study the "Influence of tillage practices on chemical properties of soil and on uptake and dry matter production by pulse crops grown in rice fallows". The experiment was designed using a split plot design, which replicated thrice having three tillage practices (T_1: Zero tillage; T_2: Reduced tillage; T_3: Minimum tillage) in main plots and four *rabi* pulse crops (S_1: Chickpea; S_2: Mungbean; S_3: Urdbean; S_4: Cowpea) in sub-plots with total twelve treatment combinations. The experiment's results revealed that tillage practices and pulse crops had a significant influence on soil nutrient status. Zero tillage (T_1) recorded significantly higher soil available N (243.3 kg ha^{-1}), P (21.1 kg ha^{-1}) and K (339.6 kg ha^{-1}) respectively. Among sub-plot treatments, rice-chickpea sequence recorded higher available N, P and K (245.9, 20.7 and 345.4 kg ha^{-1} respectively) in soil. On the other hand, on a mean basis, reduced tillage (T_2) recorded higher dry matter production and nutrient uptake by pulse crops grown in rice fallows.
Keywords **:** Dry matter, Nutrient uptake, Pulse crops, Rice fallows, Tillage

Introduction

The resources of poor farmers cannot meet the expenses of fertilizer and irrigation requirements for the succeeding *rabi* crops after rice harvest (Geethika *et al*., 2024). In India, approximately 11.7 million hectares of land remain fallow after the *kharif* rice harvest, particularly in rainfed regions (DAC, 2011). Hence, there is a need for policy support, research and technological intervention for utilizing and improving the productivity of rice fallows.

These rice fallows can be a great opportunity for agricultural intensification through the cultivation of pulse crops during the *rabi* (winter) season. Under rice fallow conditions, the productivity of crops can be increased since the system utilizes the residual moisture for their growth and development (Geethika *et al*., 2024). Being short-duration crops and having the ability to grow by utilizing residual moisture in fallows, pulses can be best suited into rice fallows. Pulses have unique ability to fix nitrogen with the help of N-fixing bacteria (Hellriegel, 1886). Hence they can be best fitted into rice fallows (Ali *et al*., 2014).

The total world acreage under pulses is about 93.93 Mha with production of 90.24 Mt at 961 kg ha^{-1} yield. India, with >34 Mha of pulses cultivation area, is the largest pulse producing country in the world. It ranks first in area with 36% and production with 27% respectively (DPD 2023-24).

Pulses are well known for their role in improving soil fertility and biodiversity, facilitating intercropping and providing global food security as well as nutritional security. They contain about 20–25% protein by weight, which is double the protein content of wheat and three times that of rice (APEDA 2023-24), making them an excellent source of protein. For a long time, people in India were more focused on a cereal-centric diet, which increased the rate of malnutrition in people. However, today policymakers, researchers, and nutritionists are shifting their interest from calorie intake to nutrition, which is increasing demand for pulses. To meet rising demand and increase population growth, pulse production must increase from 26 Mt to 32 Mt by year 2030 and 39 Mt by year 2050 (DPD 2023-24) in this context, it is critical to increase pulse production through scientific methodologies, skilled operations, and policymaking.

For successful cultivation of pulse crops after harvest of rice, suitable conservation tillage is required for conserving residual moisture, better germination and growth of crops. So this experiment was intended to study and find out the suitable tillage practice and pulse crops for sustainable intensification of rice fallows.

Materials and Methods

The experiment was carried out on medium black soil at a research farm in Siddapur, Regional Agricultural Research Station (RARS), Warangal (18°05'35.9"N latitude and 79°35'48.6"E longitude and 351m above mean sea level). The experimental site is in Southern Telangana Agro-Climatic Zone. There was no rainfall recorded during the crop growth period. The trial included 12 treatment combinations organized in a split-plot design with three replications. In the main-plot there were three different tillage methods, namely, T_1: zero tillage (herbicide spray + seed dibbling). T_2: Reduced tillage (two cultivators and one rotavator). T_3: Minimum tillage (once cultivator and once rotavator). Among sub-plot there were four pulse crops, viz S_1: Chickpea (NBeG-3- duration 90 days), S_2: Mungbean (MGG-351- duration 70 days), S_3: Urdbean (LBG-752- duration 75 days), and S_4: Cowpea (TCP-9- duration 125 days). This experiment was carried out in a total of 36 plots, each having a gross plot size of 6.0 m x 4.0 m and a net plot size of 4.2 m x 3.6 m, with 0.5 m between each plot and a 1 m gap between replications. The soil was silt loam with a pH of 7.66, an EC of 0.38 d Sm^{-1} and the available N, P, and K were 219.1, 21.3 and 361.4 kg ha^{-1} respectively. Immediately after harvesting rice, the field was prepared according to the treatments and all crops. Fertilizers were applied as per recommendations and seeds were sown with prescribed seed rates according to crops. All crops were sown with spacing of 30 x 10 cm between rows and plants. Soil samples were collected and analysed using standard analytical procedures for soil chemical properties. Plant samples were collected at harvest, thoroughly washed, oven-dried, and ground to a powder. Later digested with H_2SO_4 and diacid (HNO_3:$HClO_4$ in a 9:4 ratio) to estimate N, P, and K. Nutrient uptake was calculated using their concentration in seed/stover and their yield.

Note: Data on dry matter and nutrient uptake by plants were compared on a mean basis without statistical analysis because different crops with genetically distinct characteristics have different uptake abilities. As a result, different crops could not be compared in subplots, whereas the influence of tillage and crops on soil chemical properties was statistically analysed and the data was interpreted using Fisher's split-plot design.

Results and Discussion

Soil chemical properties

Tillage had a significant impact on post-harvest soil N, P, and K levels (Table 1). Among main plot treatments, zero tillage (243.3 kg ha^{-1}) had significantly higher available N, followed by minimum tillage (235.8 kg ha^{-1}), which was on par with reduced tillage (229.8 kg ha^{-1}). A similar trend was observed in available P, where zero tillage (21.1 kg ha^{-1}) was significantly superior to minimum tillage (18.5 kg ha^{-1}), which was on par with reduced tillage (17.4 kg ha^{-1}). On the other hand, zero tillage (339.6 kg ha^{-1}) had the highest available K, being on par with minimum tillage (330.6 kg ha^{-1}), which was further on par with reduced tillage (325.1 kg ha^{-1}). Increasing the intensity of tillage among treatments increased uptake by plants which in turn resulted in reduced availability of nutrients in soil (Pratibha *et al*., 1997). Higher soil available N, P, and K in zero tillage could be attributed to lower crop nutrient uptake due to soil compaction, as well as the addition of nutrients from residue, resulting in more available nutrients. These results are in conformity with Singh *et al.* (2021).

Among subplot treatments, pulse crops had a significant impact on soil nutrient status. The status of N in rice-chickpea (245.9 kg ha^{-1}) was significantly higher and improved by 12.2 % compared to the initial N status in soil. And it was on par with the rice-urdbean (241.2 kg ha^{-1}) sequence, which increased N status by 10.1 %, that was further on par with the rice-mungbean sequence (238.1 kg ha^{-1}), which improved N status by 8.6 %, whereas the rice-cowpea sequence (219.9 kg ha^{-1}) had significantly lower available N in soil. The increase in soil N status could be attributed to biological nitrogen fixation (BNF) by pulse crops, even though nutrients supplied by fertilizers were removed through plant uptake. However, soil P and K levels decreased due to plant uptake. Rice-chickpea sequence had the highest available P and K (20.7 and 345.4 kg ha^{-1}), followed by rice-urdbean (19.8 and 338.7 kg ha^{-1}) and rice-mungbean (18.3 and 326.7 kg ha^{-1}), while rice-cowpea sequence had the lowest (17.2 and 316.4 kg ha^{-1}). Since cowpea has a longer growing season and a taller, denser growth habit than other crops, it can remove most of the nutrients from the soil as uptake. As a result, cowpea had significantly lower soil N, P, and K levels. There was no interaction between tillage and crops because all crops responded equally to tillage practices. These results are in conformity with (Pratibha *et al*., 1997). However, tillage and pulse crops had no significant influence on soil organic carbon content, though a slight increase in zero tillage was noticed, which might be due to residue retention. Similarly, pH and EC were not influenced by tillage and pulse crops, as they remained statistically non-significant.

Uptake and dry matter

The influence of different tillage methods on N, P and K uptake in *rabi* pulse crops was illustrated in Fig. 2. The data from Table 2 revealed that on a mean comparative basis, higher total N uptake in chickpea, mungbean, urdbean and cowpea (43.9, 68.7, 59.8 and 89.1 kg ha^{-1} respectively) was observed with reduced tillage, followed by minimum tillage (40.2, 66, 57.8 and 86.8 kg ha^{-1} respectively) and zero tillage (35.7, 62.1,51.8 and 81.9 kg ha^{-1} respectively). Higher N uptake in reduced tillage could be attributed to lesser weed competition for nutrients, compared to zero tillage with higher weed infestation. And intensive tillage treatment provides better growth conditions for uptake of nutrients (Dodwadiya and Sharma, 2012). Similarly, on a mean comparative basis, reduced tillage reported higher P and K removal in chickpea (12.2 and 38.9 kg ha^{-1}), mungbean (16 and 58.6 kg ha^{-1}), urdbean (14.3 and 46.3 kg ha^{-1}), and cowpea (21.4 and 68.2 kg ha^{-1}), followed by minimum and zero tillage across all crops. This could be possibly due to lower penetration resistance in reduced tillage, which improved root growth for better nutrient uptake, as well as improved soil physical conditions, which led to increased translocation, particularly of phosphorus to reproductive parts, whereas in zero tillage, soil compaction resulted in poor root growth and nutrient uptake. These findings are consistent with those of Kar *et al.* (2021), who revealed that all cropping systems showed higher nutrient uptake in reduced tillage compared to zero tillage.

The influence of tillage on dry matter production (kg ha^{-1}) of pulse crops was illustrated in Fig. 1. The results showed that among tillage practices, on a mean basis, reduced tillage recorded higher dry matter accumulation in all crops at the harvest stage, followed by minimum tillage and zero tillage (Table 2). Improved nutrient uptake by crops in reduced tillage resulted in higher dry matter production. Similar results were reported by (Kumar and Angadi, 2016) who revealed that as the intensity of tillage increased among treatments, dry matter production also increased.

Conclusion

The study highlights that adopting reduced tillage in rice fallows is a sustainable approach, as it enhances crop productivity by improving nutrient uptake and dry matter. While zero tillage with no soil disturbance retained more post-harvest soil nutrients with lesser crop performance. To diversify rice fallows with pulse crops, it is best to choose pulse crops like mungbean or urdbean, which provide higher productivity in a short duration compared to long-duration crops like cowpea.

Table 1: Soil chemical properties as influenced by tillage practices and *rabi* pulse crops

Treatment	pH	EC (d Sm^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Main plots (Tillage practices)						
T_1: Zero tillage	7.69	0.30	0.53	243.3	21.1	339.6
T_2: Reduced tillage	7.71	0.31	0.50	229.8	17.4	325.1
T_3: Minimum tillage	7.67	0.29	0.51	235.8	18.5	330.6
SEm (±)	0.02	0.01	0.01	1.65	0.33	3.50
CD (p=0.05)	NS	NS	NS	6.49	1.31	13.75
Sub plots (Rabi pulses)						
S_1: Chickpea	7.69	0.29	0.51	245.9	20.7	345.4
S_2: Mungbean	7.71	0.31	0.52	238.1	18.3	326.7
S_3: Urdbean	7.68	0.30	0.50	241.2	19.8	338.7
S_4: Cowpea	7.69	0.29	0.53	219.9	17.2	316.4
SEm (±)	0.01	0.007	0.01	2.66	0.33	3.68
CD (p=0.05)	NS	NS	NS	7.89	0.98	10.94

Sub treatment at same level of main treatment						
SEm (±)	0.02	0.013	0.02	4.60	0.57	6.38
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Main treatment at same level of sub treatment						
SEm (±)	0.03	0.015	0.03	4.31	0.60	6.54
CD (p=0.05)	NS	NS	NS	NS	NS	NS

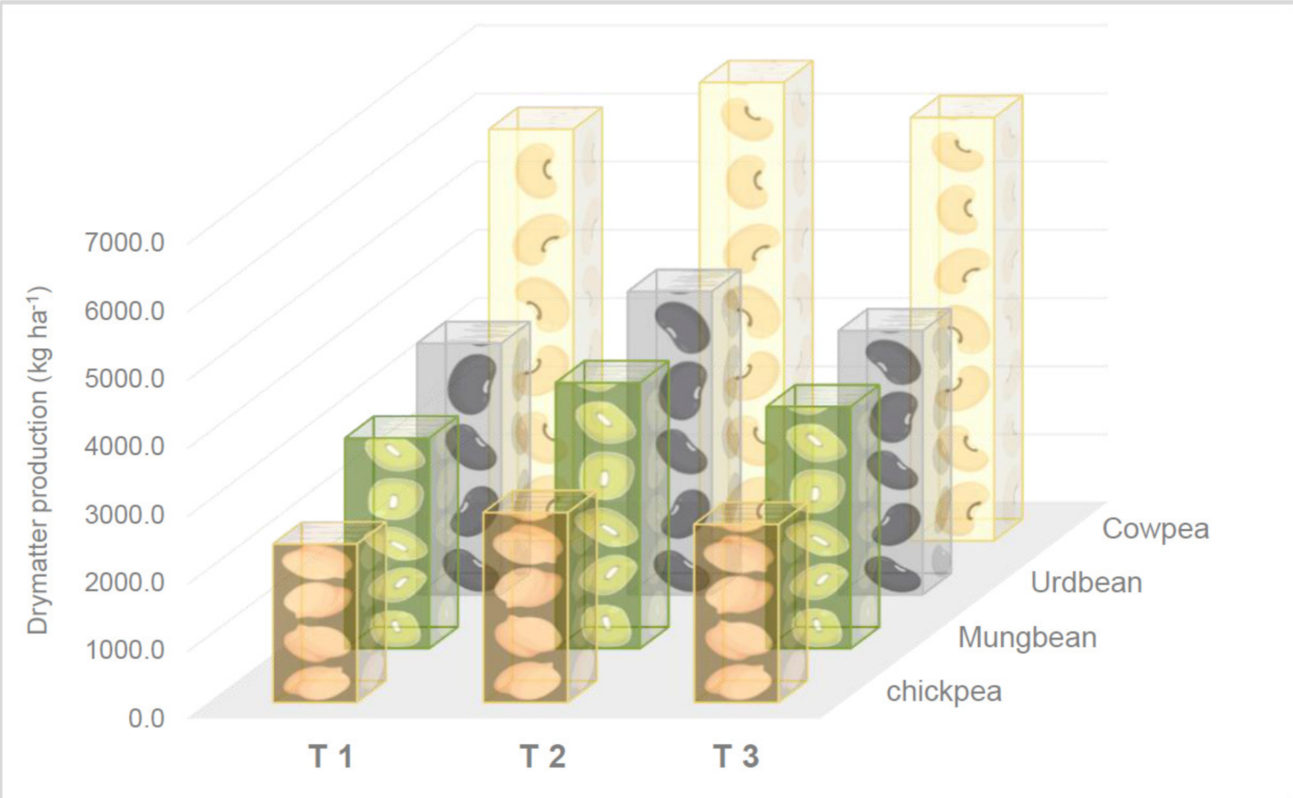

Fig. 1: Influence of tillage on dry matter production (kg ha^{-1}) of pulse crops at harvest stage

Table 2: Nutrient uptake (kg ha^{-1}) and dry matter (kg ha^{-1}) of *rabi* pulse crops as influenced by tillage practices

Treatment	N uptake kg ha^{-1}			P uptake kg ha^{-1}			K uptake kg ha^{-1}			Dry matter at Harvest stage (kg ha^{-1})
	Seed	Haulm	Total	Seed	Haulm	Total	Seed	Haulm	Total	
Chickpea										
T_1	24.7	11.0	35.7	7	3.4	10.4	10.8	23.2	34	2256
T_2	29.3	14.6	43.9	7.9	4.3	12.2	12.7	26.2	38.9	2816
T_3	27.0	13.2	40.2	7.8	3.9	11.7	12.5	24.7	37.2	2742
Mungbean										
T_1	42.4	19.7	62.1	8.8	4.3	13.1	17.8	33.9	51.7	3107
T_2	46.5	22.2	68.7	10.2	5.8	16	19.4	39.2	58.6	3819
T_3	45.3	20.7	66	9.6	5.4	15	19.3	37.5	56.8	3668
Urdbean										
T_1	34.9	16.9	51.8	8.7	4.4	13.1	13.8	27.0	40.8	3695
T_2	39.9	19.9	59.8	9.1	5.2	14.3	16.6	29.7	46.3	4356
T_3	38.7	19.1	57.8	9.1	4.8	13.9	15.7	28.8	44.5	3979
Cowpea										
T_1	61.3	20.6	81.9	11.2	6.9	18.1	21.0	41.5	62.5	5863
T_2	65.6	23.5	89.1	13.1	8.3	21.4	22.2	46.0	68.2	6524
T_3	64.4	22.4	86.8	12.4	7.7	20.1	21.1	44.7	65.8	6406

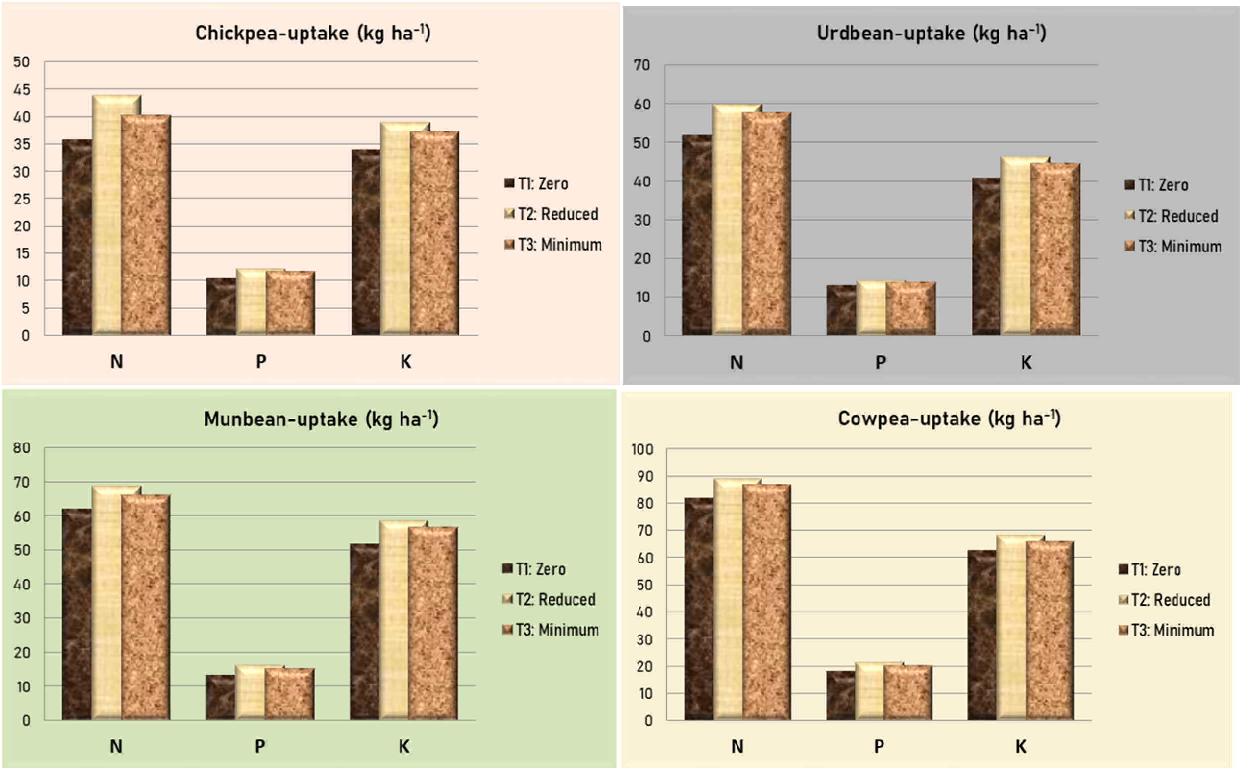

Fig. 2 : Influence of different tillage methods on N, P and K uptake in *rabi* pulse crops

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Declarations

Conflicts of interest/Competing interests

not applicable

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