

Effect of Nutrient Management through Target Yield Approach on Uptake and Soil Microflora in Maize – Wheat/Chickpea Sequence Cropping System under Different Tillage Practices

**K. A. Hiremath^{1*}, A. S. Halepyati¹, B. M. Dodamani¹, M. A. Bellakki²,
B. M. Chittapur¹, P. H. Kuchanur³ and Amaregouda⁴**

¹Department of Agronomy, University of Agricultural Sciences, Raichur – 584 104 (Karnataka), India.

²Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences,
Raichur – 584 104 (Karnataka), India.

³Department of Genetics and Plant Breeding, University of Agricultural Sciences, Raichur – 584 104
(Karnataka), India.

⁴Department of Crop Physiology, University of Agricultural Sciences, Raichur – 584 104 (Karnataka),
India.

Authors' contributions

This work was carried out in collaboration among all authors. Author KAH designed the study, performed the statistical analysis, interpretation, wrote the protocol and wrote the first draft of the manuscript. Author ASH as a chairman, guided me in designing the study. Authors BMD and MAB managed the analysis of study. Authors MAB, BMC, PHK and Amaregouda managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i1830782

Editor(s):

(1) Dr. Nhamo Nhamo, Zimbabwe Open University, Zimbabwe.

Reviewers:

(1) Juan Jose Aparicio Porres, Universidad Mayor de San Andres, Bolivia.

(2) Benmati Mahboub, Ecole National Supérieur de Biotechnologie, Algeria.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/57769>

Original Research Article

Received 20 April 2020

Accepted 27 June 2020

Published 13 July 2020

ABSTRACT

A field trial was carried out during July month of kharif and October month of rabi seasons of 2013-14 and 2014-15 at Agricultural Research Station, Bheemarayanagudi to study the effect of nutrient management through target yield approach on uptake and soil microflora in maize – wheat/chickpea sequence cropping system under different tillage practices. The results indicated

*Corresponding author: E-mail: kahiremath@rediffmail.com;

that the yield parameters of maize, wheat and chickpea at harvest did not influence due to tillage practices. All these yield parameters were relatively higher in zero tillage with mulch at 5 t ha⁻¹ when compared to conventional tillage. Grain and stover yield of maize did not differ significantly due to different tillage management practices. But, zero tillage with mulch at 5 t ha⁻¹ produced relatively higher yield (65.9 q ha⁻¹) than the zero tillage (64.3 q ha⁻¹) followed by conventional tillage (55.8 q ha⁻¹). The higher organic carbon and soil microflora at different stages were noticed with zero tillage with mulch at 5 t ha⁻¹. The higher available NPK and their uptake by maize crop were also recorded in zero tillage with mulch at 5 t ha⁻¹ followed by zero tillage compared to conventional tillage and zero tillage. The lower available NPK and their uptake by maize crop were recorded in conventional tillage and RDF. Further, due to nutrient management through target yield approach, the yield parameters of maize were differed significantly. Target yield of 10 t ha⁻¹ exhibited significantly higher yield attributes at harvest when compared to other treatments except the targeted yield of 8 t ha⁻¹ and 150% RDF. The lowest values of these attributes were recorded in farmer's practice of nutrient management followed by RDF. The grain yield and stover yield (69.9 q ha⁻¹ and 89.5 q ha⁻¹, respectively) of maize was significantly higher with a targeted yield of 10 t ha⁻¹ followed by targeted yield of 8 t ha⁻¹ and 150% RDF. The lowest grain and stover yield (53.6 q ha⁻¹ and 74.3 q ha⁻¹, respectively) was recorded in farmers practice followed by RDF. Significantly higher soil microflora, available NPK and their uptake by the maize crop was noticed in target yield of 10 t ha⁻¹ followed by targeted yield of 8 t ha⁻¹ and 150% RDF as compared to other treatments. The lowest soil microflora, available nitrogen, phosphorus, and potassium (NPK) and their uptake by the maize was recorded in farmers practice followed by RDF. The same trend was followed statistically for organic carbon due to different treatments. Non significant differences for grain and stover yield of maize was recorded due to interaction of tillage and nutrient management practices. Similar trend was also followed due to interaction of tillage and nutrient management practices for succeeding wheat and chickpea. The yield and yield parameters of wheat and chickpea did not differ due to tillage practices and target yield approaches followed for maize. Maize equivalent yield of wheat and chickpea and system productivity were followed same trend as that of maize yield. Among different tillage practices, zero tillage and zero tillage with mulch at 5 t ha⁻¹ were recorded maximum net returns and higher BC ratio. Similarly, among different nutrient management practices, the target yield of 10 t ha⁻¹ followed by targeted yield of 8 t ha⁻¹ was recorded maximum net returns and higher BC ratio as compare to other treatments.

Keywords: Tillage; crop residue; mulch; target yield; maize equivalent yield; system productivity.

1. INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in India after wheat and rice. Currently, it is cultivated in an area of 9.60 m ha with a production of 27.10 m t and productivity of 2600 kg ha⁻¹ [1]. In Karnataka, maize is grown over an area of 1.12 m ha with a production of 3.31 m t and productivity of 3400 kg ha⁻¹ [1]. Since maize is an exhaustive crop, the nutrient requirement cannot be supplied only through native nutrient reserves; the additional nutrients can be met by fertilizer application. In Karnataka maize yield is low due to imbalanced application of fertilizers. The recommendation of a fertilizer dose is a challenge to scientists as it should meet both nutrient demand of crop and sustain the production system. Site-specific nutrient management (SSNM) is one tool employed to apply nutrients at right rate, right source, right time with right method based on the soil test value for getting higher yields and to save

nutrients. Among the several technologies for nutrient management, site-specific nutrient management is seen as one of the main strategies in present scenario of agriculture and become one of the techniques more relevant to Indian Farming community. Due to the importance of plant nutrition and its influence on crop yield and quality, it is expected that SSNM (Target yield approach) would improve the economic and environmental outcome of crop production. It is an approach for need-based feeding of the crops with nutrients [2]. The approach further aims at increasing farmers profit by achieving the goal of maximum crop yields. Further under irrigated condition, there is an opportunity to take two crops in a year following maize-wheat and maize-chickpea cropping systems in order to get efficient utilization of existing available resources. Such kind of cropping system needs full season nutrient requirement through nutrient supply system on sustainable manner. Many options are available

to fulfill the requirement of nutrients regularly in cropping system while keeping the productivity of land sustainable.

Further, the application of inorganic fertilizers even in balanced form may not sustain soil fertility and productivity under continuous cropping. Zero tillage with crop residues management is capable of increasing the soil health and quality by improving soil properties, minimizing soil erosion, soil water evaporation and conserving soil moisture which has been well documented. Hence, reduced tillage practices have been widely used in the last decade as an attractive alternative over conventional tillage practice because of their potential to reduce production or operating costs and benefit for the environment and can save considerable time with seed bed preparation compared with conventional tillage practices. As tillage is mainly confined to surface layers, it increases microbial biomass [3]. The zero tillage with direct seeding in presence of residues is capable of building organic matter and soil microbial biomass (bacteria, actinomycetes and fungi). Crop residue retention increases the populations of actinomycetes, total bacteria and fluorescent *Pseudomonas* under both zero and conventional tillage [4].

Keeping these points in view, the present investigation was planned to study the effect of nutrient management through Target yield approach on uptake and soil microflora in maize – wheat/chickpea sequence cropping system under different Tillage practices.

2. MATERIALS AND METHODS

The trial was conducted during *kharif* and *rabi* seasons of 2013-14 and 2014-15 at Agricultural Research Station, Bheemarayanagudi, University of Agricultural Sciences, Raichur, Karnataka. The soil of the experimental site was medium deep black soil with 7.90 pH. The soil was low in available nitrogen (207 kg ha⁻¹), high in available phosphorus (52.3 kg ha⁻¹) and high in available potassium (344 kg ha⁻¹). The organic carbon content of the soil was low (0.49%). The rainfall received during cropping seasons of 2013 - 14 and 2014 was 759 mm and 646 mm respectively. The experiment was laid out in split plot design consists of three main plots *viz.*, conventional tillage, zero tillage and zero tillage with mulch @ 5 t ha⁻¹ and six sub plots *viz.*, target yield (6 t ha⁻¹), target yield (8 t ha⁻¹), target yield (10 t ha⁻¹), RDF, 150% RDF and farmers practice in three

replications. The hybrid 900M for maize, variety DWR 198 for wheat and JG 11 for chickpea were used. The fertilizers were applied as per treatments for maize. The amount of fertilizer for target yield approach in maize under different tillage operations was calculated by using the formulae,

$$FA = \text{Nutrient uptake by crop per tonne grain yield} \times T \times \% \text{ EFR}$$

% EFR = 30% more or less fertilizer to be applied as per the soil supply capacity for N, P₂O₅ and K₂O as low (30% more than the calculated value), medium (as per the calculated value) and high (30% less than the calculated value). The recommended dose of fertilizer 100: 75 : 50 kg N, P₂O₅ and K₂O for wheat and 50: 25 kg N and P₂O₅ for chickpea as sequence crops in *rabi* season was applied in the form of urea, DAP and MOP. Pre emergent herbicide pendimethalin 30 EC @ 2.5 kg ha⁻¹ was used to control weeds in initial stage in maize as well as in wheat. Post emergent herbicide 2, 4 - D 80% @ 1.25 kg ha⁻¹ was used for suppressing the weed growth in maize and wheat at 25 DAS. Other agronomic practices were followed commonly in all the treatments as per the recommendations.

For nutrients uptake study the samples collected were ground into fine powder and passed through a 40 mm mesh sieve and used for analysis of nitrogen, phosphorus and potassium concentration in plants. Nitrogen was estimated by Kjeldahl's method, phosphorus by Vanado-molybdophosphoric yellow colour method and potassium content was determined using flame photometry method. The uptake of nutrients by different parts of maize plants was worked out by multiplying the nutrient content and dry matter yield of the plant (+ grain) as given in the following formula and it was expressed in terms of kg ha⁻¹.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = (\text{Nutrient content (\%)/100}) \times \text{dry weight (kg ha}^{-1}\text{)}$$

The organic carbon content of a finely ground and sieved in 0.2 mm sized sieve soil sample was determined by Walkely and Black's wet oxidation method. It was expressed in per cent. Available N, P and K were determined by using modified alkaline potassium permanganate method, olsen's method and flame Photometer respectively and expressed them in kg ha⁻¹. The microbial population in the soil before, middle and harvest of the crop was determined by serial

dilution plate count method. Soil samples from different treatments were collected separately. Ten grams of soil (treatment wise) was mixed in 90 ml sterilized water blank to 10^{-1} dilutions. Subsequent dilutions up to 10^{-6} were made by transferring serially one ml of each dilution to nine ml sterilized water blanks. The population of total *bacteria*, *fungi* and *actinomycetes* were estimated by serial dilution plate count technique and by plating on appropriate media viz., soil extract agar, martins Rose Bengal *Streptomycin* sulphate agar and Kustras agar, respectively. The inoculated plates were kept for incubation at $30^{\circ}\text{C} \pm 1^{\circ}\text{C}$ for a week and emerged colonies were counted.

Observations on yield attributes and yield were recorded at harvest of the crop as per the standard procedures.

Harvest index was calculated by using the formula as outlined by Donald and Hamblin, (1962).

$$\text{Harvest index} = (\text{Seed yield (kg ha}^{-1}) / \text{Seed (kg ha}^{-1}) + \text{haulm yield (kg ha}^{-1}))$$

Maize equivalent yield was calculated by using the formula as

$$\text{Maize equivalent yield} = (\text{Yield of wheat (q ha}^{-1}) \times \text{price of wheat (Rs. q}^{-1}) / \text{Price of maize (Rs. q}^{-1})$$

System productivity was calculated by using the formula as

$$\text{System productivity} = \text{Yield of maize crop} + \text{maize equivalent yield of wheat / chickpea}$$

The cost of inputs that were prevailing at the time of their use was considered for working out the economics of various treatment combinations. Gross return was calculated on the basis of their prevailing market sale rate and the yield of produce per hectare. A net return ha^{-1} was calculated by deducting the cost of cultivation from gross income per hectare. Benefit cost ratio was worked as follows.

$$\text{Benefit cost ratio} = (\text{Gross returns (Rs ha}^{-1}) / \text{Cost of cultivation (Rs ha}^{-1}))$$

All the data obtained were statistically analyzed using the F test procedures given by Gomez and Gomez [5]. Critical difference (CD) values were calculated for the $P=0.05$ whenever F test was found significant.

3. RESULTS AND DISCUSSION

3.1 Effect of Crop Residue and Tillage Practices and Target Yield Approaches on Maize

The data indicated that the yield components such as cob length, cob girth, number of grains per cob, grain weight and test weight did not differ due to tillage practices. However, these parameters were shown numerically higher values in zero tillage with mulch @ 5 t ha^{-1} when compared to conventional tillage. Grain and straw yield of maize did not differ significantly due to different tillage management practices. But, zero tillage with mulch @ 5 t ha^{-1} produced relatively higher yield (65.9 q ha^{-1}) than the zero tillage (64.3 q ha^{-1}) followed by conventional tillage (55.8 q ha^{-1}). The increase in grain yield of maize due to zero tillage with mulch @ 5 t ha^{-1} was 2.5 and 18.10 per cent over zero tillage and conventional tillage. The higher NPK uptake was recorded in zero tillage with mulch @ 5 t ha^{-1} followed by zero tillage compared to conventional tillage and zero tillage. The lower uptake of NPK was recorded in conventional tillage and RDF. The increase in the yield might be attributed due to increased yield parameters like cob length, number of grains per cob, cob girth, number of grains per cob, grain weight and test weight. These results are in conformity with findings of Singh et al. [6], Bahar [7] and Yaseen et al. [8].

Further, due to target yield approach, the yield attributing characters viz., cob length (15.65 cm), number of grains per cob (462.30), cob girth (13.91 cm), grain weight per plant (188.77 g) and 100 grain weight (25.14) were recorded significantly higher in targeted yield of 10 t ha^{-1} followed by target yield of 8 t ha^{-1} compared to other treatments. The lowest values of these attributes were recorded in farmers practice of nutrient management followed by RDF. The grain yield and stover yield (69.9 q ha^{-1} and 89.5 q ha^{-1} , respectively) of maize was significantly higher with targeted yield of 10 t ha^{-1} followed by targeted yield of 8 t ha^{-1} and 150% RDF. The lowest grain and stover yield (53.6 q ha^{-1} and 74.3 q ha^{-1} , respectively) was recorded in farmers practice followed by RDF. The grain yield of maize increased in targeted yield of 10 t ha^{-1} was 30.4 per cent over farmers practice and 24.4 per cent over RDF. Significantly higher NPK uptake was noticed in target yield of 10 t ha^{-1} followed by targeted yield of 8 t ha^{-1} and 150% RDF as compared to other treatments. The lowest uptake was recorded in farmers practice

followed by RDF. The increase in the yield might be attributed due to increased yield parameters like cob length, number of grains per cob, cob girth, number of grains per cob, grain weight and test weight. The increase in number of grains per cob could be attributed to increase in cob length and cob girth. Results are in agreement with findings of Memon et al. [9], Aikins et al. [10] and Prashanth and Patil [11]. Interaction effect due to tillage and nutrient management through target yield approaches had no significant differences for grain and stover yield of maize.

3.2 Effect of Crop Residue, Tillage Practices and Target Yield Approach on Succeeding Wheat

Non significant differences were observed for yield components namely number of effective tillers, number of grains per spike, grain weight and test weight. All these yield parameters were relatively higher in zero tillage with mulch @ 5 t ha⁻¹ compared to conventional tillage. Grain and straw yield of wheat did not differ significantly due to different tillage management practices. However, zero tillage with mulch @ 5 t ha⁻¹ produced relatively higher yield (20.32 q ha⁻¹) closely followed by zero tillage (19.56 q ha⁻¹) than conventional tillage (18.99 q ha⁻¹). The increase in yield of wheat due to zero tillage with mulch @ 5 t ha⁻¹ was 7.0 per cent over conventional tillage. These results are in conformity with findings of Bhattacharyya et al. (2008) and Jat et al. [12].

Significantly higher yield attributing characters viz., effective number of tillers (205.68), number of grains per spike (32.27), grain weight per spike (1.91 g) and test weight (39.27 g) of wheat recorded significantly higher in targeted yield of 10 t ha⁻¹ followed by target yield of 8 t ha⁻¹ and RDF compared to other treatments. The lowest values of these attributes (190.17, 25.84, 1.25 g and 31.52, respectively) were recorded in farmers practice of nutrient management. The grain yield (21.72 q ha⁻¹) and straw yield (29.47 q ha⁻¹) of wheat was significantly higher in targeted yield of 10 t ha⁻¹ followed by targeted yield of 8 t ha⁻¹ and 150% RDF. The lowest grain yield (16.17 q ha⁻¹) and straw yield (20.86 q ha⁻¹) were recorded in farmers practice followed by RDF. The grain yield increased in targeted yield of 10 t ha⁻¹ by 34.32 per cent over farmers practice and 19.14 per cent over RDF. The increase in grain yield could be attributed to higher value of yield contributing parameters namely; number of effective tillers, number of grains per spike, grain

weight and test weight. Results are in agreement with findings of Sepat and Rai [13] and Sharma and Jain [14]. Interaction effect due to tillage and nutrient management through target yield approaches had no significant differences for grain and straw yield of wheat.

3.3 Effect of Crop Residue, Tillage Practices and Target Yield Approach on Succeeding Chickpea

Non significant differences for yield components such as number of pods per plant, pod weight, seed weight and test weight were observed. All these yield attributes were relatively higher in zero tillage with mulch @ 5 t ha⁻¹ compared to conventional tillage. Seed and haulm yield of maize did not differ significantly due to different tillage management practices. However, zero tillage with mulch @ 5 t ha⁻¹ produced relatively higher seed and haulm yield (11.79 q ha⁻¹ and 15.21 q ha⁻¹ respectively) closely followed by zero tillage (11.40 q ha⁻¹ and 15.04 q ha⁻¹, respectively) and conventional tillage (11.08 q ha⁻¹ and 14.91 q ha⁻¹, respectively). The increase in seed yield could be attributed to relatively higher yield components such as number of pods per plant, pod weight, seed weight and test weight. Several workers suggested higher productivity of crops due to residual effect of nutrients on succeeding crops. Bhattacharyya et al. (2008), Gangawar et al. [15] and Jat et al. [12] the increase in seed yield due to zero tillage with mulch @ 5 t ha⁻¹ was 3.42 and 6.41 per cent over zero tillage and conventional tillage respectively.

The yield attributing characters also did not differ due to target yield approaches. Numerically higher yield attributing characters of chickpea viz., number of pods per plant (20.82), pod weight (8.67 g), seed weight (8.27 g) and test weight (24.79 g) were recorded in targeted yield of 10 t ha⁻¹ followed by target yield of 8 t ha⁻¹ and 15% RDF compared to other treatments. The lowest values of these attributes (17.99, 7.19 g, 6.92 g, and 21.45 g respectively) were recorded in farmers practice of nutrient management and RDF. The seed and haulm yield of chickpea were relatively higher in targeted yield of 10 t ha⁻¹ (12.34 q ha⁻¹ and 15.48 q ha⁻¹, respectively) followed by targeted yield of 8 t ha⁻¹ and 150% RDF. The lowest seed and haulm yield was recorded in farmers practice (10.57 q ha⁻¹ and 14.68 q ha⁻¹, respectively) followed by RDF (11.04 q ha⁻¹ and 14.79 q ha⁻¹, respectively). The yield increased in targeted yield of 10 t ha⁻¹ was

by 14.37 per cent over farmers practice and 11.77 per cent over RDF. Non significant differences for seed and haulm yield of chickpea was noticed due to interaction of tillage and nutrient management through target yield approaches.

3.4 Effect of Crop Residue, Tillage Practices and Target Yield Approach on Soil Fertility

The organic carbon, available nitrogen and potassium did not differ due to tillage practices. However, numerically higher values of these parameters were recorded in zero tillage with 5 t ha⁻¹ followed by zero tillage as compare to conventional tillage. Further the available phosphorus was differed significantly due to tillage practices. Significantly higher available phosphorus was recorded in zero tillage with 5 t ha⁻¹ followed by zero tillage as compare to conventional tillage. The soil microflora at initial and middle stage was influenced significantly by tillage practices and did not differ at harvest. Significantly higher microbial activity was recorded in zero tillage with mulch @ 5 t ha⁻¹ followed by zero tillage as compared to conventional tillage. The increase in the values of these parameters could be due to accumulation of organic matter through zero tillage or zero tillage with mulch. The Results are in agreement with findings of Gentile et al. [16], Jat et al. [12] and Prashanth and Patil [11]. Due to target yield approach for nutrient management, the organic carbon and available nitrogen did not differ. Statistically, higher values of these parameters were noticed in target yield of 10 t ha⁻¹ followed by target yield of 8 t ha⁻¹ as compared to other treatments. Significantly higher available phosphorus and potassium were registered with target yield of 10 t ha⁻¹ as compared to farmers' practice and target yield of 6 t ha⁻¹. The soil microflora at initial and middle stage was influenced significantly by tillage practices and did not differ at harvest and followed same trend as that of available phosphorus and potassium. The interaction effect due to tillage practices as well as target yield approaches did not differ.

3.5 Economics of Maize – Wheat and Maize – Chickpea Cropping Systems

3.5.1 Maize – wheat cropping system

Maize equivalent yield of wheat was not influenced due to different tillage practices. However, higher maize equivalent yield was

obtained in zero tillage with mulch @ 5 t ha⁻¹. The lower maize equivalent yield was recorded with conventional tillage. The different target yield approaches differed significantly. Significantly higher maize equivalent yield was recorded in target yield of 10 t ha⁻¹. The lowest maize equivalent yield was obtained in conventional tillage followed by RDF. The interaction effect due to tillage practices as well as target yield approaches did not differ.

System productivity of maize – wheat cropping system differed significantly due to different tillage practices. Zero tillage with mulch @ 5 t ha⁻¹ recorded significantly higher system productivity. The lowest system productivity was registered with conventional tillage. The different target yield approaches differed significantly for system productivity. Target yield of 10 t ha⁻¹ was significantly higher for system productivity. Significantly the lowest system productivity was recorded in conventional tillage. The interaction effect due to tillage practices as well as target yield approaches did not differ.

Significantly higher net returns (Rs.80,272 ha⁻¹) were recorded with zero tillage with mulch @ 5 t ha⁻¹ followed by zero tillage (Rs.78,181 ha⁻¹) compared to conventional tillage (Rs. 62,112 ha⁻¹). Further, net returns and B:C ratio differed significantly due to target yield approach. Significantly higher net returns (Rs.85,105 ha⁻¹) was recorded in target yield of 10 t ha⁻¹ followed by target yield of 8 t ha⁻¹ (Rs. 80,565 ha⁻¹). The lowest net returns (Rs.61,119 ha⁻¹) was obtained with farmers practice followed by RDF (Rs.63,672 ha⁻¹). The interaction effect due to tillage practices as well as target yield approaches did not differ.

3.5.2 Maize – chickpea cropping system

The different tillage practices did not influence the maize equivalent yield. However, higher maize equivalent yield was recorded with zero tillage with mulch @ 5 t ha⁻¹. The lower maize equivalent yield (28.00 q ha⁻¹) was noticed with conventional tillage. The different target yield approaches did not differ. But, target yield of 10 t ha⁻¹ recorded numerically higher maize equivalent yield. The lowest maize equivalent yield was recorded in conventional tillage followed by RDF. The interaction effect due to tillage practices as well as target yield approaches did not differ. The different tillage practices influenced the system productivity of maize – chickpea cropping system.

Table 1. Organic carbon, available N, P and K of soil, uptake by maize and soil micro flora as influenced by different tillage and target yield approaches in maize – wheat cropping system (mean of two years)

Treatment	Organic carbon (%)	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)	N Uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	Soil micro flora (No.x10 ⁶ CFU g ⁻¹)		
								Initial	Middle	At harvest
Main plots (M)										
M ₁ - Conventional tillage	0.44	207.51	44.80	288.50	138.41	27.64	98.49	45.60	54.25	47.63
M ₂ - Zero tillage	0.51	238.94	50.51	332.20	159.36	31.90	113.54	52.46	61.03	53.80
M ₃ - Zero tillage with mulch @ 5 t / ha	0.54	243.91	51.88	339.10	162.68	32.45	115.62	54.60	63.22	55.72
S. Em ±	0.02	13.00	1.11	17.40	8.66	1.72	6.12	2.14	2.40	2.90
C.D. (0.05)	NS	NS	4.47	NS	NS	NS	NS	5.89	6.72	NS
Sub plots (S)										
S ₁ - Targeted yield (6 t / ha)	0.50	231.30	49.18	321.57	154.28	30.99	109.78	51.21	59.72	52.10
S ₂ - Targeted yield (8 t / ha)	0.52	243.16	52.25	339.81	163.03	32.57	116.00	54.19	62.84	55.37
S ₃ - Targeted yield (10 t / ha)	0.56	259.53	55.48	360.83	173.08	34.59	123.17	58.06	66.71	58.11
S ₄ - RDF	0.44	208.62	44.18	290.05	139.15	27.80	99.01	45.17	53.89	48.30
S ₅ - 150% RDF	0.51	238.85	50.67	330.32	158.48	31.50	112.76	52.54	61.19	53.50
S ₆ - Farmer's practice	0.43	199.26	42.64	277.02	132.90	26.56	94.57	44.13	52.66	46.91
S. Em±	0.04	21.50	2.10	16.10	7.71	1.54	5.48	2.81	2.81	4.00
C.D. (0.05)	NS	NS	6.10	46.60	22.40	4.48	15.91	8.14	8.16	NS
Interaction (M x S)										
S. Em±	0.05	20.82	2.71	28.94	13.88	2.78	9.87	4.93	4.94	4.24
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant RDF: Recommended dose of fertilizers

Table 2. Yield parameters of maize, wheat and chickpea at harvest as influenced by different tillage practices and target yield approaches in maize - wheat / chickpea cropping system (mean of two years)

Treatment	Maize					Wheat				Chickpea			
	Cob length (cm)	Cob girth (cm)	Number of grains per cob	Grain weight (g plant ⁻¹)	Test weight (g)	Number of effective tillers	Number of grains per spike	Grain weight per spike (g)	Test weight (g)	Number of pods (Plant ⁻¹)	Pod weight (g plant ⁻¹)	Seed weight (g plant ⁻¹)	100 grain weight (g)
Main plots (M)													
M ₁ - Conventional tillage	12.71	10.99	348.44	169.88	22.70	193.61	27.22	1.50	34.70	17.75	7.27	6.87	21.66
M ₂ - Zero tillage	14.32	12.51	406.15	179.70	23.89	196.59	28.20	1.57	35.76	19.42	8.14	7.84	22.47
M ₃ - Zero tillage with mulch @ 5 t / ha	14.92	12.87	426.71	184.91	24.58	198.88	30.39	1.66	37.53	20.81	8.49	8.24	23.64
S. Em ±	0.76	0.67	27.90	5.30	0.67	8.27	1.13	0.05	1.02	1.67	0.47	0.23	1.24
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plots (S)													
S ₁ - Targeted yield (6 t / ha)	14.09	12.08	402.19	178.49	23.75	193.77	28.00	1.53	35.62	19.04	7.95	7.57	21.56
S ₂ - Targeted yield (8 t / ha)	15.04	13.22	431.80	186.20	24.83	199.26	29.70	1.75	38.94	20.25	8.29	8.01	23.44
S ₃ - Targeted yield (10 t / ha)	15.65	13.91	462.30	188.77	25.14	205.68	32.27	1.91	39.27	20.82	8.67	8.27	24.79
S ₄ - RDF	12.57	10.60	333.73	169.82	22.58	193.22	27.16	1.42	33.16	18.32	7.60	7.27	21.72
S ₅ - 150% RDF	14.47	12.79	419.33	181.87	24.29	196.06	28.45	1.60	37.48	19.54	8.09	7.85	22.57
S ₆ - Farmer's practice	12.07	10.15	313.26	163.80	21.76	190.17	25.84	1.25	31.52	17.99	7.19	6.92	21.45
S. Em ±	0.70	0.70	29.19	5.44	0.72	6.09	1.52	0.18	2.22	1.19	0.55	0.37	1.32
C.D. (0.05)	2.06	2.03	84.71	15.78	2.08	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (M x S)													
S. Em ±	1.23	1.23	51.55	9.52	1.26	12.69	1.35	0.12	2.49	2.52	0.10	0.55	2.43
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant RDF: Recommended dose of fertilizers

Table 3. Grain yield, stover yield and harvest index of maize and grain yield, straw yield and harvest index of wheat as influenced by different tillage practices and target yield approaches in maize - wheat cropping system (mean of two years)

Treatment	Maize		Wheat		Maize equivalent yield of wheat (q ha ⁻¹)	System productivity (q ha ⁻¹)	Net returns (Rs ha ⁻¹)	B C ratio
	Grain yield of maize (q ha ⁻¹)	Straw yield (q ha ⁻¹)	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)				
Main plots (M)								
M ₁ - Conventional tillage	55.8	76.5	18.99	25.20	21.5	77.3	62112	1.55
M ₂ - Zero tillage	64.3	84.2	19.56	25.94	22.1	86.5	78181	2.19
M ₃ - Zero tillage with mulch @ 5 t / ha	65.9	88.3	20.32	26.85	23.0	88.9	80272	2.18
S. Em ±	3.60	4.21	0.57	0.89	1.19	1.46	1920	0.06
C.D. (0.05)	NS	NS	NS	NS	NS	5.99	7745	0.24
Sub plots (S)								
S ₁ - Targeted yield (6 t / ha)	62.7	83.5	20.20	26.47	22.9	85.5	76472	2.13
S ₂ - Targeted yield (8 t / ha)	65.8	86.7	20.91	27.84	23.7	89.5	80565	2.17
S ₃ - Targeted yield (10 t / ha)	69.9	89.5	21.72	29.47	24.6	94.5	85105	2.18
S ₄ - RDF	56.2	78.3	18.23	24.63	20.6	76.8	63672	1.72
S ₅ - 150% RDF	64.0	85.7	20.49	26.70	23.2	87.2	74198	1.84
S ₆ - Farmer's practice	53.6	74.3	16.17	20.86	18.3	71.9	61119	1.85
S. Em±	3.1	2.9	0.95	1.19	0.97	3.04	4006	0.11
C.D. (0.05)	9.1	9.0	NS	NS	2.80	8.82	11626	0.32
Interaction (M x S)								
S. Em±	5.6	5.5	1.39	2.08	1.94	3.58	4705	0.14
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant RDF: Recommended dose of fertilizers

Table 4. Grain yield, haulm yield, harvest index and economics of chickpea as influenced by different tillage practices and target yield approaches in maize - chickpea cropping system (mean of two years)

Treatment	Chickpea			Maize equivalent yield of chickpea (q ha ⁻¹)	System productivity (q ha ⁻¹)	Net returns (Rs ha ⁻¹)	B C ratio
	Seed yield (q ha ⁻¹)	Haulm yield (q ha ⁻¹)	Harvest Index				
Main plots (M)							
M ₁ - Conventional tillage	11.08	14.91	0.43	28.00	83.82	69527	1.70
M ₂ - Zero tillage	11.40	15.04	0.43	28.79	93.12	85779	2.33
M ₃ - Zero tillage with mulch @ 5 t / ha	11.79	15.21	0.43	29.77	95.66	88017	2.32
S. Em ±	0.55	0.28	0.01	0.49	1.33	1747	0.05
C.D. (0.05)	NS	NS	NS	NS	5.36	7042	0.21
Sub plots (S)							
S ₁ - Targeted yield (6 t / ha)	11.29	14.97	0.43	28.52	91.19	82750	2.23
S ₂ - Targeted yield (8 t / ha)	11.71	15.28	0.43	29.58	95.37	87188	2.28
S ₃ - Targeted yield (10 t / ha)	12.34	15.48	0.44	31.16	101.02	92570	2.30
S ₄ - RDF	11.04	14.79	0.42	27.89	84.06	72076	1.88
S ₅ - 150% RDF	11.59	15.09	0.43	29.29	93.26	81045	1.95
S ₆ - Farmer's practice	10.57	14.68	0.41	26.68	80.31	71018	2.07
S. Em±	0.42	0.26	0.01	1.11	2.79	3679	0.10
C.D. (0.05)	NS	NS	NS	NS	8.10	10678	0.28
Interaction (M x S)							
S. Em±	0.82	0.50	0.02	1.20	3.26	4,279	0.12
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS

NS – Non significant RDF: Recommended dose of fertilizers

Significantly higher system productivity was recorded with zero tillage with mulch @ 5 t ha⁻¹. Significantly the lowest system productivity was noticed with conventional tillage. The system productivity of maize – chickpea differed significantly due to target yield approaches. Target yield of 10 t ha⁻¹ recorded significantly higher system productivity. The lowest system productivity was recorded in conventional tillage followed by RDF. The interaction effect due to tillage practices as well as target yield approaches did not differ.

Net returns and B:C were affected significantly due to tillage practices. Significantly higher net returns (Rs.88,017 ha⁻¹) was recorded with zero tillage with mulch @ 5 t ha⁻¹ followed by zero tillage. But, B:C ratio (2.33) in zero tillage was slightly higher than zero tillage with mulch @ 5t ha⁻¹ (2.32). The slightly higher B:C ratio might be due to cost on mulching. The net returns and B:C ratio differed significantly due to target yield approaches. Significantly higher net returns (Rs.92,570 ha⁻¹) and B:C ratio (2.30) were recorded in target yield of 10 t ha⁻¹ followed by target yield of 8 t ha⁻¹. Significantly lower B:C ratio was recorded with RDF (1.88) followed by 150% RDF (1.95) and found to be on par with farmers' practice (2.07). The lowest net returns (Rs.71,018 ha⁻¹) was obtained with farmers practice followed by RDF. The interaction effect due to tillage practices as well as target yield approaches did not differ.

4. CONCLUSION

Based on the investigation carried out in maize – wheat / chickpea cropping system under irrigation, the zero tillage with mulch is found to be a best resource management practice which could save the cost on cultivation and obtained higher productivity of cropping system by improving the soil fertility. Application of nutrients through targeted yield approach of 8 and 10 t ha⁻¹ is more useful and profitable since benefit cost ratio is higher compared to application of farmers practice and RDF. Application of nutrients through targeted yield approach in combination with organic source is more useful in maintenance of soil organic carbon, available NPK and microbial load and sustainability.

ACKNOWLEDGEMENT

The senior author is thankful to University of Agricultural Sciences, Raichur for providing an

opportunity to study the higher education on deputation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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