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The impact of conservation tillage and weed management practices on nutrient uptake by crops, weeds in *kharif* maize, and their impacts on Kernal yield and the available nutrient status of soil after harvest of crop

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Abstract
A field experiment was conducted at AICRP on Weed Management, MRS, Hebbal, Bengaluru during *Kharif* 2019 and 2020 to examine the effects of various conservation tillage and weed management approaches on crop nutrient uptake, weeds in *kharif* maize, and their effects on Kernal production, the available nutrient status of soil after *kharif* maize harvest, and B:C ratio. The experiment was laid out in a split-plot design with five main plots of different tillage treatments and three sub-plots of different weed management practices replicated thrice. The main plot tillage treatments consisted of conventional tillage, zero tillage, minimum tillage, minimum tillage + zero tillage (combination), and permanent bed. The intensity of tillage and various weed management practices had a significant effect on maize crop nutrient uptake at harvest. In compared to zero tillage (117.9, 28.1, and 91.1 kg N, P_2O_5 and K_2O ha^{-1}, respectively), permanent raised beds have significantly higher nitrogen, phosphorus, and potassium uptake (142.0, 34.8, and 105.4 kg N, P_2O_5 and K_2O ha^{-1}, respectively). The maize crop nutrient uptake at harvest was significantly affected by weed management practices. Integrated weed management (138.9, 33.74, and 108.8 kg N, P_2O_5 and K_2O ha^{-1}, respectively) had significantly higher nitrogen, phosphorus, and potassium uptake than unweeded (control) (97.8, 22.95, and 70.9 kg N, P_2O_5 and K_2O ha^{-1}, respectively).

Keywords: Weed management, minimum tillage, nutrient uptake, integrated weed, management

Introduction
In South Asia, maize production for both human consumption and animal feed is increasing. Winter wheat, monsoon rice, and other crops are being replaced by maize since it can be cultivated all year round in this environment, has a high yield potential, and is in great demand. Maize is resistant to shifting climatic circumstances because it experiences reduced photorespiration (C4 plant). With a yearly production of around 24 million t, maize is produced on 9.2 million ha in India. Sustainable farming practises have emerged in recent years as a result of growing consumer concern about concerns including food quality, environmental safety, and soil protection (Belak *et al*. 2014) [1]. In addition to affecting crop development, the many agronomic factors of land and fertilizer management also affect the diversity and expansion of related weeds (Kumar *et al*. 2018) [26]. Because they absorb nutrients more quickly than crops do, weeds compete with crops for nutrients. The amount and source of nutrients, particularly nitrogen, will have an impact on the composition of the weed community (Ghosh *et al*. 2018) [9].

The maize-soybean relay intercropping method may encourage effective use of crop and soil nutrients, control the nitrogen cycle of the soil, and greatly raise the rate at which nitrogen fertiliser is used in maize and soybean in the southwest of China. The grain production could be increased, the land equivalent ratio could be improved, and the land equivalent ratio could even grow to 2.2 with this intercropping technique (Yang *et al*. 2017; Du *et al*. 2018) [29]. According to recent research, the nitrogen uptake of grain was 8.5% lower in monoculture soybean than in intercropping soybean, maize-soybean intercropping had a 105.1% higher nitrogen use efficiency than monoculture maize (Chen *et al*. 2017) [3], and wheat-maize-soybean relay intercropping had a higher total nitrogen accumulation than monocultures (Yong *et al*. 2015) [30]. According to He *et al.* (2013), a change in the makeup of the microbial community caused the plant P absorption in maize-soybean intercropping to increase.

Material and Methods

The field experiment was conducted during *Kharif*, 2019 and 2020 to study the weed management in maize based cropping system under conservation agriculture. The field study was conducted at AICRP on weed management, Main Research Station, Hebbal, Bengaluru. The soil of the experimental site was sandy loam with a pH of 6.34 and with low organic carbon content (0.34 %). The field experiment was conducted using split-plot design with five main plots on different tillage treatments and three sub-plots of different weed management practices replicated thrice. The main plot of tillage treatments consisted of conventional tillage, zero tillage, minimum tillage, minimum tillage + zero tillage (combination) and permanent raised bed. The sub-plot weed management practices consisted of W_1- Recommended herbicides (Pendimethalin-750 g ha^{-1} (PE) + *fb* tembotrione 120 g ha^{-1} + atrazine 500 g ha^{-1}), W_2-Integrated weed management (Pendimethalin-750 g ha^{-1} (PE) + Hand weeding at 30 DAS) and W_3- Unweeded (control). The experiment consists of five main tillage treatments and three sub weed management treatments which were replicated thrice in split-plot design.

The maize (MAH 14-5) was sown at a spacing of 60 cm x 30 cm between row and plants. Fertilizer level of 150 kg N, 75 kg P_2O_5, and 40 kg K_2O ha^{-1} was applied as per the recommendation, all the fertilizers were given as basal dose only. The pre-emergence and post-emergence herbicides were applied using a spray volume of 750 litres ha^{-1} and 500 liters ha^{-1} with a knapsack sprayer having WFN nozzle. The data on species wise weed count in a quadrant of 50 cm x 50 cm were collected at 60 DAS (days after sowing). Data averaged over three replications. From density of major weed species per m^2 and density of weeds category- sedges, grass and broad leaf weeds on 60 DAS were worked out. In addition, total dry weight was also recorded at 60 DAS. The data on weeds density and dry weight were subjected to the transformation of square root (x+0.5) depending on the variability and weed index calculated by using the formula suggested by Gill and Vijaykumar (1969) [10]. Leaf area index was calculated at 60 DAS by using the below formula given by Watson (1947) [27].

$$\text{LAI} = \frac{\text{Leaf area of plant}}{\text{Ground area covered by plant}}$$

The data collected on different traits were statistically analyzed using the standard procedure and the results were tested at a five per cent level of significance as given by Gomez and Gomez (1984) [11]. The least significant differences were used to compare treatment means.

Results and Discussion

Nutrient Uptake by crop

The intensity of tillage and various weed management practices had a significant effect on maize crop nutrient uptake at harvest. In compared to zero tillage (117.9, 28.1, and 91.1 kg N, P_2O_5 and K_2O ha^{-1}, respectively), permanent raised beds have significantly higher nitrogen, phosphorus, and potassium uptake (142.0, 34.8, and 105.4 kg N, P_2O_5 and K_2O ha^{-1}, respectively) (Table 1). We show that when these cropping conditions were paired with minimum tillage, the best maize production and nitrogen uptake were achieved. As previously documented for soils managed with non-inversion tillage compared to those managed with ploughing, a greater amount of water stable aggregates and soil organic matter (SOM) in the surface soil layers under minimum tillage than under conventional tillage in our study likely boosted soil water holding capacity and infiltration rate. Because of the increased soil organic matter (SOM), which is documented to contribute significantly to plant requirements, especially during early growth stages, nutrient concentration in the surface soil layers was likely higher under conservation tillage than under conventional tillage. Furthermore, it has been demonstrated that reduced nitrogen leaching occurs in minimum tillage soils than in conventional tillage soils, leading to maize root growth. Similar finding were noticed by Powlson *et al*. (2011) [25], Fraser *et al*. (2013) [7], Busari *et al*. (2015b) [2] and Guzzetti *et al*. (2020) [13].

The maize crop nutrient uptake at harvest was significantly affected by weed management practices. Integrated weed management (138.9, 33.74, and 108.8 kg N, P_2O_5 and K_2O ha^{-1}, respectively) had significantly higher nitrogen, phosphorus, and potassium uptake than unweeded (control) (97.8, 22.95, and 70.9 kg N, P_2O_5 and K_2O ha^{-1}, respectively). (Table 1). Nutrient uptake is the total uptake (grain + stover) of nutrients by the crop. Maximum nitrogen, phosphorus, and potassium uptake in greengram and maize is generally recorded with application of pendimethalin at 0.75 kg ha^{-1} followed by hand weeding at 30 DAS, which significantly increased the nutrient uptake as compared to weedy control, This agrees with the findings of Gaikwad *et al.,* (2009) [8], Kade *et al*., (2014) [16], Komal *et al*., (2015) [19], Lal *et al*., (2017) [21] and Muthuram *et al*., (2018) [23].

Nutrient depletion by weeds

Weeds are the primary competitors for nutrient uptake in crop fields. As a result, adequate weed management practices must be adopted in order to achieve satisfactory crop yields. The effects of various tillage and weed management practices on weed nutrient uptake at harvest are discussed.

Among the different tillage practices, the permanent raised beds have shown significantly lower uptake of nutrients (8.8, 1.51 and 7.23 kg N, P_2O_5 and K_2O ha^{-1}, respectively) by weeds as compared to zero tillage (11.4, 1.95 and 8.69 kg N, P_2O_5 and K_2O ha^{-1}, respectively) (Table. 2). The increased nutrient uptake in zero tillage was related to an increase in weed density and dry weight at different crop growth stages due to inadequate weed control due to no soil inversion, no post-emergence chemical or physical weed management, and a higher soil weed seed bank. Monsefi *et al.* (2016) found that weeds in zero tillage-raised bed systems assimilate the most N, P_2O_5, and K_2O when compared to conventional tillage-raised bed systems.

Weed management practices have a significant impact on weed nutrient uptake at harvest. Integrated weed management (7.6, 1.27, and 6.22 kg N, P_2O_5 and K_2O ha^{-1}, respectively) resulted in considerably lower nitrogen, phosphorus, and potassium uptake as compared to unweeded (control) (15.0, 2.67, and 11.1 kg N, P_2O_5 and K_2O ha^{-1}, respectively). (Table. 2). Weed growth was vigorous in unweeded check treatments, resulting in greater N, P, and K nutrient uptake Chhodavadia *et al*. (2014) [4]. The findings are agreement with Younesabadi *et al*. (2013) [31], Kade *et al*. (2014) [16], Owla *et al*. (2015) [24] and Lal *et al*. (2017) [21].

Available nutrient status of soil after harvest of crops

Tillage and weed management practices have had a significant impact on the availability of nitrogen, phosphorus, and potassium in the soil after maize harvest.

Among different tillage practises, zero tillage has significantly higher soil available nitrogen, phosphorous, and potassium in soil following harvest of maize (246.0, 21.5, and 246.0 kg N, P_2O_5 and K_2O ha^{-1}, respectively), followed by minimum tillage and permanent raised beds (Table 3). The better soil structure conditions are often advantageous for improved nutrient retention capacity in conservation tillage compared with conventional tillage. The proportion of organic phosphorus in total phosphorus was significantly higher under no tillage than under conventional tillage. Crop residue return and decomposition improve soil physical characteristics by increasing soil nutrients (SOC, soil N, P, and K) and macro aggregates in the soil layer, as well as promoting the distribution of soil porosity. It might be due to greater soil available nutrients in zero tillage were attributed to lower nutrient uptake due to maize's lower kernel and Stover yield, whereas the lower soil available nutrients in permanent raised beds were attributed to higher nutrient uptake due to maize's higher kernel and Stover yield. The findings agree with Feng *et al*., (2011) [6], Gómez-Rey *et al*., (2012) [12], Zhang *et al*., (2012) [33], Wei *et al.* (2014) [28], and Zhang *et al*., (2018) [32].
When compared to un weeded (control) (245.6, 20.9, and 243.6 kg N, P_2O_5 and K_2O ha^{-1}, respectively), integrated weed management (224.5, 19.1, and 225.5 kg N, P_2O_5 and K_2O ha^{-1}, respectively) resulted in significantly lower nitrogen, phosphorus, and potassium availability of nutrients in soil (Table 3). The greater soil available nutrients in un weeded (control) might be due to being attributed to lower nutrient uptake due to maize's lower kernel and stover yield, whereas the lower soil available nutrients in integrated weed management were attributed to higher nutrient uptake due to maize's higher kernel and stover yield. Similar results are found by Kaur *et al*. (2010) [17], Chhodavadia *et al*., (2014) [4], and Lal *et al*., (2017) [21].

Crop yield

The plots imposed with Permanent raised bed significantly recorded the highest seed yield (3.36 t ha^{-1}), compared to other tillage practices (Table 4). Similar results were found by Jat *et al.* (2011) reported that permanent bed planting gave maximum system productivity during both years as compared to conventional tillage in maize-wheat-mungbean cropping systems. Among the weed management practices, the plots treated with pendimethalin 750 g ha^{-1} followed by hand weeding at 30 DAS recorded the highest seed yield (3.43 t ha^{-1}) compared to the use of only recommended herbicide (3.15 t ha^{-1}). Unweeded control recorded the lowest seed yield (2.47 t ha^{-1}) due to less effective control of weeds throughout the crop growth period. Unweeded control lowered the yield as a result of the severe competition of weeds particularly broadleaf weeds and sedges. Similar results were found by Rajeshkumar *et al.* (2018) [26] when pendimethalin at 0.75 kg ha^{-1} was applied followed by one rotary hoeing on 35 DAS resulted. Similarly, a field experiment conducted at Ludhiana (India), found about 25 per cent higher grain yield with a permanent bed planting of maize than flat sowing (Kaur and Mahey, 2012) [18] The highest yield in bed planting with the bed was due to increased number of cobs per plant and more grains per cob than flat sowing.

Economics

The higher B: C ratio (1.44) was noticed in Permanent raised bed and Integrated weed management (1.45) (pendimethalin 750 g h^{-1} a followed by Hand weeding at 30 DAS). The least was recorded in un weeded control (1.28) treatment (Table 4).

Table 1: Nitrogen, Phosphorus and Potassium uptake by maize (*kharif*) at harvest as influenced by different tillage and weed management practices

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Tillage practices (T)									
T_1= Conventional tillage (CT)	124.8	123.3	124.0	30.6	29.7	30.1	95.9	91.7	93.8
T_2= Zero Tillage (ZT)	121.4	114.3	117.9	27.9	28.3	28.1	90.8	91.3	91.1
T_3= Minimum Tillage (MT)	118.9	110.7	114.8	26.8	27.4	27.1	88.6	89.9	89.2
T_4= Zero Tillage (ZT)	111.5	106.2	108.8	25.3	25.3	25.3	84.4	84.6	84.5
T_5= Permanent bed	151.9	132.1	142.0	33.1	36.5	34.8	100.6	110.2	105.4
S.Em±	5.54	4.18	3.47	1.28	1.56	1.01	2.95	3.75	2.39
LSD (P=0.05)	18.07	13.63	10.40	4.18	5.10	3.03	9.63	12.24	7.16
Weed management(W)									
W_1= Recommended herbicide-Pendimethalin-750 g ha^{-1} (PE) + *fb* tembotrione 120 g ha^{-1} + atrazine 500 g ha^{-1}	132.2	123.4	127.8	30.3	30.9	30.6	98.1	99.3	98.7
W_2= IWM – Pendimethalin 750 g ha^{-1} PE +Hand weeding at 30 DAS	146.0	131.8	138.9	32.6	34.7	33.7	105.8	111.9	108.8
W_3= Unweeded control	98.9	96.8	97.8	23.2	22.6	22.9	72.2	69.5	70.9
S.Em±	4.75	4.16	3.16	1.06	1.21	0.80	2.95	3.59	2.32
LSD (P=0.05)	3.63	14.03	9.03	3.13	3.57	2.30	8.70	10.59	6.64
Interaction (TxW)									
S.Em±	9.60	7.24	9.28	2.22	2.71	2.51	5.12	6.50	6.64
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Nutrient depletion by weeds in maize (kharif) at harvest as influenced by different tillage and weed management practices

Treatments	Nitrogen depletion (kg ha^{-1})			Phosphorus depletion (kg ha^{-1})			Potassium depletion (kg ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Tillage practices (T)									
T_1= Conventional tillage (CT)	12.2	9.1	10.6	2.07	1.55	1.81	9.57	7.08	8.33
T_2= Zero Tillage (ZT)	12.0	10.8	11.4	2.05	1.85	1.95	9.16	8.23	8.69
T_3= Minimum Tillage (MT)	15.7	10.8	13.3	2.70	1.88	2.29	12.21	8.39	10.30
T_4= Zero Tillage (ZT)	13.6	10.7	12.2	2.33	1.86	2.09	10.70	8.28	9.49
T_5= Permanent bed	9.3	8.3	8.8	1.59	1.43	1.51	7.72	6.75	7.23
S.Em±	0.75	0.59	0.47	0.11	0.10	0.07	0.47	0.39	0.30
LSD (P=0.05)	2.44	1.91	1.42	0.36	0.32	0.22	1.54	1.26	0.91
Weed management(W)									
W_1= Recommended herbicide-Pendimethalin-750 g ha^{-1} (PE) + *fb* tembotrione 120 g ha^{-1} + atrazine 500 g ha^{-1}	13.5	8.8	11.2	2.25	1.46	1.85	10.87	7.23	9.05
W_2= IWM – Pendimethalin 750 g ha^{-1} PE +Hand weeding at 30 DAS	10.5	4.7	7.6	1.75	0.78	1.27	8.56	3.89	6.22
W_3= Unweeded control	13.7	16.3	15.0	2.45	2.90	2.67	10.18	12.12	11.15
S.Em±	0.67	0.57	0.44	0.09	0.09	0.06	0.35	0.30	0.23
LSD (P=0.05)	1.98	1.69	1.26	0.26	0.26	0.18	1.03	0.88	0.66
Interaction (TxW)									
S.Em±	1.29	1.01	1.28	0.19	0.17	0.19	0.82	0.67	0.74
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Available nutrient status in soil after harvest of maize (*kharif*) as influenced by different tillage and weed management practices

Treatments	Available Nitrogen (kg ha^{-1})			Available Phosphorus (kg P_2O_5 ha^{-1})			Available Potassium (kg K_2O ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Tillage practices (T)									
T_1= Conventional tillage (CT)	242.3	214.0	228.1	19.9	17.9	18.9	236.9	217.7	227.3
T_2= Zero Tillage (ZT)	248.1	225.3	236.7	21.3	20.5	20.9	242.7	228.7	235.7
T_3= Minimum Tillage (MT)	255.6	229.5	242.5	21.5	21.0	21.2	249.1	236.2	242.6
T_4= Zero Tillage (ZT)	257.3	234.6	246.0	21.9	21.1	21.5	251.9	240.2	246.0
T_5= Permanent bed	238.2	209.8	224.0	18.1	17.4	17.8	230.5	214.4	222.5
S.Em±	4.01	5.13	3.25	0.56	0.70	0.45	4.32	5.08	3.34
LSD (P=0.05)	13.08	16.71	9.76	1.83	2.28	1.35	14.10	16.57	10.00
Weed management(W)									
W_1= Recommended herbicide-Pendimethalin-750 g ha^{-1} (PE) + *fb* tembotrione 120 g ha^{-1} + atrazine 500 g ha^{-1}	248.9	223.7	236.3	20.7	19.6	20.2	243.5	227.2	235.4
W_2= IWM – Pendimethalin 750 g ha^{-1} PE +Hand weeding at 30 DAS	237.8	211.2	224.5	19.7	18.4	19.1	232.4	218.6	225.5
W_3= Unweeded control	258.2	233.0	245.6	21.2	20.6	20.9	250.8	236.5	243.6
S.Em±	4.19	4.55	3.09	0.40	0.44	0.30	4.24	3.86	2.87
LSD (P=0.05)	12.36	13.42	8.84	1.19	1.30	0.85	12.52	11.38	8.20
Interaction (TxW)									
S.Em±	6.95	8.88	8.92	0.97	1.21	1.02	7.49	8.80	8.63
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Kernel yield, and B: C ratio in maize as influenced by tillage and weed management practices

Treatments	Kernal yield (t ha^{-1})			B:C ratio		
	2019	2020	Pooled	2019	2020	Pooled
Tillage practices (T)						
T_1= Conventional tillage (CT)	3.11	2.92	3.02	1.47	1.18	1.33
T_2= Zero Tillage (ZT)	2.90	2.93	2.91	1.47	1.26	1.37
T_3= Minimum Tillage (MT)	2.87	2.94	2.91	1.46	1.25	1.36
T_4= Zero Tillage (ZT)	2.87	2.9	2.89	1.43	1.25	1.34
T_5= Permanent bed	3.19	3.52	3.36	1.49	1.38	1.44
S.Em±	0.03	0.05	0.03	NA	NA	NA
LSD (P=0.05)	0.10	0.16	0.10			
Weed management(W)						
W_1= Recommended herbicide-Pendimethalin-750 g ha^{-1} (PE) + *fb* tembotrione 120 g ha^{-1} + atrazine 500 g ha^{-1}	3.12	3.18	3.15	1.46	1.26	1.36
W_2= IWM – Pendimethalin 750 g ha^{-1} PE +Hand weeding at 30 DAS	3.34	3.51	3.43	1.53	1.37	1.45
W_3= Unweeded control	2.5	2.44	2.47	1.40	1.17	1.28
S.Em±	0.05	0.05	0.03	NA	NA	NA
LSD (P=0.05)	0.12	0.14	0.09			
Interaction (TxW)						
S.Em±	0.09	0.11	0.08	NA	NA	NA
LSD (P=0.05)	NS	NS	NS			

Conclusion

Results of the experiment indicated that *Kharif*- maize performed better under permanent bed due to better establishment, high seedling vigor and superior growth as a consequence of better land preparations and preparation of permanent beds compared to other tillage practices. It might be due to greater soil available nutrients in zero tillage were attributed to lower nutrient uptake due to maize's lower kernel and Stover yield, whereas the lower soil available nutrients in permanent raised beds were attributed to higher nutrient uptake due to maize's higher kernel and Stover yield. Among weed management practices, integrated approach of pre-emergence herbicide followed by one hand weeding at 30 DAS effectively controlled the weeds up to the critical period of weed competition in maize, thereby resulted in significantly superior growth and growth attributes over-application of pre-emergence herbicide alone and unweeded control in a maize. The greater soil available nutrients in unweeded (control) might be due to being attributed to lower nutrient uptake due to maize's lower kernel and stover yield, whereas the lower soil available nutrients in integrated weed management were attributed to higher nutrient uptake due to maize's higher kernel and stover yield.

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