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RESEARCH ARTICLE

Boosting Grain Yield and Yield Related Traits of Spring Maize through Integrated Management Strategies

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ABSTRACT

Natural resources management strategies through the application of agronomic management practice sat the farmer field can improve per unit crop harvest which is congruent with the sustainable agricultural crop development concept. Keeping in view, a field experiment with different tillage practices along with poultry manure treatments was laid out in randomized complete block design with split plot arrangement at the Agronomic Research Area, University of Agriculture Faisalabad, Pakistan during spring 2010 and same was repeated in spring season 2011. Plant population, number of grains per cob, number of grain rows per cob, 1000-grain weight and grain yield were taken at the crop harvest during the both years of study. Significantly, better plant population (6.67 & 6.67 m^{-2}), more number of grains per cob (422.69 & 466.75), maximum number of grain rows per cob (16.7 & 17.3), higher 1000-grain weight (283.15 &351.53 g) and maximum grain yield (8.01 &9.08 Mg ha^{-1}) was recorded in T_4 followed byT_3, $T_2$and T_1 in the year 2010 and 2011, respectively. Increasing order of poultry manure (PM) levels on the maize crop significantly improved the number of grains per cob, number of grain rows per cob, 1000-grain weight and grain yield. PM_3 produced the maximum number of grains per cob (431.66 & 464.21 m^{-2}), higher number of grain rows per cob (17.1 & 17.7), maximum 1000-grain weight (278.16 & 346.73 g) and grain yield (7.92 &9.07 Mg ha^{-1}) than the PM_2 and PM_1. This study suggested that the T_3(conventional tillage practices) along with the PM_3 (@10 Mg ha^{-1}) could be helpful in achieving the maize crop genetic potential.

INTRODUCTION

Tillage has been defined as the mechanical manipulation of the soil and plant residues to prepare a seedbed where crop seeds are planted to produce grain for human and animal consumption (Reicosky and Allmaras, 2003).Among the different crop production factors; tillage is important one which contributes up to 20 % in the total crop production units (Ahmad et al., 1996). Deep tillage improved the root growth, root proliferation and increased Nitrogen Recovery Efficiency (NRE) and finally the better plant phenology than the compacted or no tilled soil (Varsa et al., 1997; Motavalli et al., 2003). Similarly, the tillage practices improved plant biological and physiological yield than the no tillage (Borghei et al., 2008; Gul et al., 2009; Marwat et al., 2007) but Choudhary and Baker (1994) concluded that the zero tillage was an efficient method of crop establishment and promoted the crop yield (Mari and Changyin, 2006) than the conventional and deep tillage.

In Pakistani soil, the organic matter is less than 5 % (Sarwar, 2005) because of high temperature, fast decomposition rate and the burning of the organic matter. Organic matter can be replenished by the addition of various natural manures and compost to the soil (Sarwar, 2005). Poultry manure provides the nutrients in very quick time and the losses of nutrients through leaching and volatilization are also very lessas compared to all other organic matters. Due to quick release of nutrients, it recharges the soil organic matter in return of good soil health, more nutrients retention, increase water holding capacity, improves soil micro flora and fauna and the water infiltration rate (Deksissa et al., 2008).Integration of poultry manure with synthetic chemical fertilizers can enhance the efficiency of nutrients uptake and availability to crop plant (Warren et al., 2006). Furthermore, the application of manure along with chemical fertilizer increases the solubility of SSP (single super phosphate) and delays P fixation (Garg and Bahla, 2008). Poultry manure treatments along the lower level of NPK produced higher values for plant height, leaf area index and biomass of corn and crop grain yield (Boateng et al., 2006).

The present study was designed to check the effect of different tillage practices and poultry manure treatments along with synthetic fertilizers on the maize grain yield and yield related attributes under tropical conditions of Faisalabad, Pakistan.

MATERIALS AND METHODS

Field experiment was conducted at the Agronomic Research Area, Department of Agronomy, University of Agriculture Faisalabad, Pakistan during spring growing season 2010 and same was repeated in spring 2011. The rice crop was harvested in the experimental area. The experimental site is located in subtropical region at 31^0 north latitude and 73^0 east longitudes on the globe with 184 m altitude. The soil samples at depth of 0-0.30 cm were taken manually with the help of soil auger before the sowing of experiment in both years (2010 & 2011). All the soil sub-samples were completely mixed and a homogenous soil sample is prepared. Then, this soil sample is subjected to various physico-chemical analyses (Table I). The experiment was carried out in Randomized Complete Block Design (RCBD) with split plot arrangement keeping the tillage practices in the main plot; zero tillage (T_1) [seed was sown with help of dibbling without ploughing], minimum tillage (T_2) [one cross cultivation with normal cultivator + Planking], conventional tillage (T_3) [3 cross cultivations with normal cultivator followed by planking], deep tillage (T_4) [two cross deep ploughing with chisel plough followed by one cultivation with normal cultivator and finally followed by planking]. Sub-plot treatments were three poultry manure levels; control [no poultry manure] (PM_1), poultry manure @ 5 Mg ha^{-1} (PM_2) and poultry manure @ 10 Mg ha^{-1}(PM_3). One year old poultry manure was used and subjected to chemical analysis before application to experimental soil in each year (Table I). The seeds were dibbled when the field was at the proper moisture contents. The irrigations were applied according to crop needs and requirements.

Pioneer 32F10 was used as test variety during the both year of study. The net plot size was 10 m × 4.5 m with R × R 75 cm and P × P 22 cm maintaining 81510 plants ha^{-1}. The crop was sown by using seed rate of 25 kg ha^{-1}. Recommended nutrients requirement of maize crop were applied both from poultry manure and chemical fertilizers after the poultry manure analysis. At first, the crop requirement was fulfilled from poultry manure and then the remaining from the chemical fertilizers. Synthetic fertilizers in the control poultry manure treatments were applied at the rate of 380 Kg nitrogen, 280 phosphorous, 192 potash per ha^{-1} (recommended dose) during the both years of study while the 5 Mg ha^{-1} poultry manure treatments were received 275, 272 kg nitrogen, 220, 216 kg phosphorous, 100, 98 kg potash and 10 Mg ha^{-1} poultry manure treatments were received the synthetic fertilizers at the rate of 168, 163 kg nitrogen, 159, 151 Phosphorous and 7, 1 kg potash during 2010 and 2011, respectively. Whole of Phosphorous, Potash and half of Nitrogen was applied at the time of sowing while remaining half of nitrogen was top dressed at the time of 2nd irrigation. Hoeing was done twice with help of a hand hoe after 1st and 2nd irrigation to curtail the weeds problem. Meteorological data of both year of crop duration was taken from the meteorological cell situated at 0.4 Km working under the Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan (Fig. 1).

The data were statistically analyzed using the Statisitca 10.1V software (Stat Soft Inc., 2012) and the significant treatments means were separated using Tukey's test at 5% probability level (Stat Soft Inc., 2005b).

RESULTS AND DISCUSSION

Plant population (m^{-2})

The data regarding to plant population (m^{-2}) showed that tillage practices significantly affected the plant population in 2010 and 2011. The maximum plant population was recorded in T_4 (6.67) which were at par with those of T_3 (6.67) andT_2 (6.66) while the minimum plant population was in the T_1 (6.56).The same data trend was recorded in the second year of research experiment (Table II).No doubt the tilled soil was loose enough to facilitate the seed in early establishment. More germinated seeds in the tilled soil(tillage treatments) was might be due to more aeration and pulverization of the soil condition which may favor the maximum seed germination resulted in maximum plant population as compared to zero tillage while in no tilled soil where less plant population was might be due to compacted soil with higher bulk density. The experiment results were close in line with those of Vetsch and Randall (2002) and Mari and Changyin (2006) who stated that the tillage supported the germinated seeds and early adjustment in the soil environment as compared to the no tilled soil. Furthermore, cool temperature in no tilled soil may hinder the seeds togerminate, causing the slower

Table 1: A. Physico-chemical analysis of soil

Characteristics	pH	EC	Organic matter	Total nitrogen	Available	
		dSm^{-1}	%	%	P (ppm)	K(ppm)
2010	7.9	1.12	0.62	0.062	7.38	290
2011	7.7	1.20	0.78	0.069	7.32	294

B. Chemical analysis of poultry manure

Compositions	Nitrogen	Phosphorous	Potassium	Dry matter
%	%	(P_2O_5) %	(K_2O)	%
2010	2.02	1.15	1.71	72.85
2011	2.06	1.17	1.73	74.03

germination and ultimately poor seedlings. The results of lessplant population in the zero tillage soil were supported by Hussain et al., (1999). Wilhelm et al. (2004) stated that the variety of tillage systems greatly affected the corn growth and development.

No doubt, the poultry manure improved the soil environmental conditions and the more rapid nutrients availability (Ali, 2005) than other organic manures but it did not affect significantly on the plant population in both year of study because for seed imbibition, the seed required a few millimeter of water which was available in the soil seeding zone that is enough for the seed germination initiation. The interactive effect of tillage and poultry manure was non-significant with significant seasonal effect.

Number of grains per cob

Significantly higher number of grains per cob was recorded in T_4 (422.69) that were statistically at par with those of T_3 (415.30) while the crop sown by T_1 had minimum number of grains per cob (377.83) in the year 2010. Similar data fashion was observed during 2011(Table II). Higher number of grains per cob in T_4 could be due to better field conditions for crop growth. In addition, longer roots in T_4 might have helped the plant to uptake more nutrients and minerals. The lower number of grains per cobin the T_1 could be due to greater impedance to root growth that disturbed the plant growth and development. These results are supported by those of Ahadiyat and Ranamukhaarachchi (2008). They reported that the reduction in number of grains per cob was due to week rooting system with higher bulk density which hindered the growth and development of maize crop in the zero tilled treatments. Wasaya et al. (2011) documented that higher number of grains per cob was noted in the deep tillage treatments as compared to conventional tillage and mould board plough treatments.

Maximum number of grains per cob (431.66) was obtained in PM_3followed by PM_2 (405.28) and minimum number of grains per cob was in PM_1 (378.55) during 2010. Similarly, the same data fashion regarding to number of grains per cob was recorded in 2011 (Table II). Higher number of grains percob in PM_3 treatments could be due to more and sustainable availability of nutrients. The experiment results are in accordance with those of Boateng et al., (2006) who documented that the poultry manure application along with the synthetic fertilizers may increase the crop growth and yield related components.

The interaction of tillage practices and poultry manure on the number of grains per cob was found significant during the year 2010 while was non-significant in 2011.Statistically more number of grains per cob was recorded in $T_4 \times PM_3$ that was at par with those of $T_3 \times PM_3$ while the lower was noted in the $T_1 \times PM_1$. Similar results were noted by those of Khan et al. (2009) stated that different organic and inorganic sources of nitrogen with till age practices observed significant on number of grains per cobs.

Number of grain rows per cob

Among tillage treatments in 2010, T_4 produced more number of grain rows per cob (16.7) followed by T_3(16.5) which did not statistically differ with those ofT_2 (16.4) and the minimum number of grain rows per cob was noted in T_1 (15.8). As regards to the year 2011, similar data trend was recorded (Table II). These results are in line with those of Rashidi and Keshavarzpour (2007). They reported that the deep tillage produced more number of grains per cob followed by conventional tillage practices. In addition to above, T_4(deep tillage practice) was performed better with more number of grain rows per cob which might be due to more soil aeration (Zorita, 2000), less soil bulk density (Hao et al., 2001), more microbial activity (Patil and Sheelavanta, 2006) and highersoil porosity (Hao et al., 2001).

The poultry manure has significantly affected the number of grain rows percob in both growing years of the experiment. With the increase in poultry manure rates, the number of grain rows per cob was also significantly increased. In 2010, the maximum number of grain rows per cob was in PM_3 treatments (17.1) followed byPM_2 treatment (16.5). The minimum number of grains rows per cob was in the control treatment (PM_1) in the year 2010 (15.3). Almost similar data trend was observed during 2011. More number of grain rows per cob in the PM_3 treatments were might be due to synergetic effect of chemical fertilizers and poultry manure on the spring maize crop while in the PM_1 treatments (no poultry manure) less number of grains per cob might be the due to less food availability for grains formation. These results are in close

Table 2: Influence of different tillage practices and poultry manure treatments on the plant population, Number of grains per cob and number of grain rows per cob during 2010 and 2011

Treatments	Plant population (m^{-2})		No. of grains cob^{-1}		No. of grain rows cob^{-1}	
	2010	2011	2010	2011	2010	2011
A Tillage practices (T)						
T_1	6.56b	6.57b	377.83c	417.05c	15.8c	16.4c
T_2	6.66a	6.66a	404.84b	452.90b	16.4b	17.2b
T_3	6.67a	6.67a	415.30ab	457.72b	16.5b	17.5ab
T_4	6.67a	6.67a	422.69a	466.75a	16.7a	17.3a
$LSD_{(0.05)}$	0.049	0.049	10.929	8.231	0.16	0.12
B Poultry manure (PM)						
PM_1	6.64	6.64	378.55c	433.98c	15.3c	16.3c
PM_2	6.64	6.64	405.28b	447.63b	16.5b	17.1b
PM_3	6.64	6.64	431.66a	464.21a	17.1a	17.7a
$LSD_{(0.05)}$	NS	NS	5.729	4.512	0.13	0.15
C. Interaction (T×PM)						
$T_1 \times PM_1$	6.55	6.56	348.52i	401.19	14.6f	15.7f
$T_1 \times PM_2$	6.56	6.57	376.15gh	418.00	16.0d	16.1ef
$T_1 \times PM_3$	6.56	6.57	408.80def	431.96	16.8bc	17.2c
$T_2 \times PM_1$	6.67	6.67	371.88h	438.94	15.5e	16.4de
$T_2 \times PM_2$	6.67	6.67	409.45def	452.50	16.5c	16.5d
$T_2 \times PM_3$	6.67	6.67	433.17abc	467.26	15.7de	17.8ab
$T_3 \times PM_1$	6.67	6.67	394.76fg	443.26	15.6e	16.5de
$T_3 \times PM_2$	6.67	6.67	414.85cde	456.90	16.7c	17.4c
$T_3 \times PM_3$	6.67	6.67	436.28ab	473.00	17.1b	17.9a
$T_4 \times PM_1$	6.67	6.67	399.03ef	452.51	16.8bc	17.3c
$T_4 \times PM_2$	6.67	6.67	420.65bcd	463.10	17.1b	17.5bc
$T_4 \times PM_3$	6.67	6.67	448.40a	484.63	17.5a	18.0a
$LSD_{(0.05)}$	NS	NS	16.788	NS	0.39	0.43

Mean not sharing the different letters in a column is statistically non-significant @ P < 5 % according to LSD; NS= Non-significant

Table 3: Influence of different tillage practices and poultry manure treatments on the 1000-grain weight and grain yield during 2010 and 2011

Treatments	1000-grain weight (g)		Grain yield (Mg ha^{-1})	
	2010	2011	2010	2011
A Tillage practices (T)				
T_1	240.31 c	289.97 c	6.37 c	7.48 c
T_2	267.98 b	341.22 b	7.68 b	8.77 b
T_3	275.64 ab	344.27 b	7.75 b	8.87 b
T_4	283.15 a	351.53 a	8.01 a	9.08 a
$LSD_{(0.05)}$	12.952	3.176	0.077	0.111
B Poultry manure (PM)				
PM_1	253.44 c	316.16 c	6.95 c	7.93 c
PM_2	268.71 b	332.35 b	7.48 b	8.65 b
PM_3	278.16 a	346.73 a	7.92 a	9.07 a
$LSD_{(0.05)}$	8.569	5.339	0.068	0.069
C. Interaction (T×PM)				
$T_1 \times PM_1$	219.38 e	270.67 h	5.90 i	6.96 h
$T_1 \times PM_2$	245.17 d	287.42 g	6.47 h	7.48 g
$T_1 \times PM_3$	256.37 bcd	311.81f	6.73 g	8.02 f
$T_2 \times PM_1$	253.98 cd	320.87 ef	7.14 f	8.12 f
$T_2 \times PM_2$	270.10 abcd	346.36 bcd	7.69 de	8.94 d
$T_2 \times PM_3$	279.85 ab	356.42 ab	8.22 b	9.24 b
$T_3 \times PM_1$	268.26 abcd	333.24 de	7.23 f	8.22 ef
$T_3 \times PM_2$	275.12 abc	342.79 bcd	7.74 d	8.98 cd
$T_3 \times PM_3$	283.54 a	356.78 ab	8.29 ab	9.42 ab
$T_4 \times PM_1$	272.14 abcd	339.84 cd	7.52 e	8.44 e
$T_4 \times PM_2$	284.44 a	352.84 abc	8.02 c	9.20b c
$T_4 \times PM_3$	292.88 a	361.92 a	8.45 a	9.61 a
$LSD_{(0.05)}$	25.112	15.648	0.201	0.203

Mean not sharing the different letters in a column is statistically non-significant @ P<5% according to LSD; NS= Non-significant

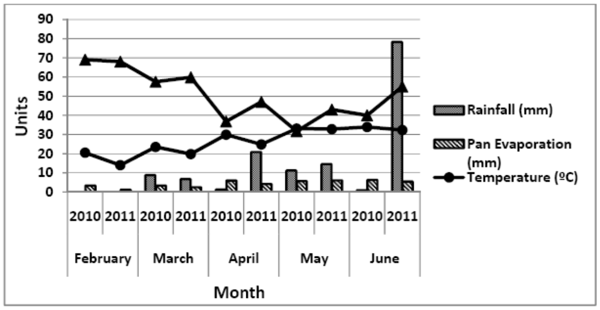

Fig. 1: Meteorological data during the crop growth season (2010 & 2011)

agreement with those of Boateng et al. (2006). They reported that the increase in the amount of poultry manure linearly increased the number of grain rows per cob.

The interactive effect of tillage practices and poultry manure treatments on the number of grain rows per cob was found significant during the both years of study. Maximum number of grain rows per cob was recorded in $T_4 \times PM_3$ that was at par with those of $T_3 \times PM_3$ and $T_2 \times PM_3$ while the lowest was in the $T_1 \times PM_1$. During the 2011 growing season, data were manifested almost similar trend as in 2010.The year effect was also significant. It might be due to more rainfall and less temperature during 2011 as compared to 2010 (Fig. I).

1000-grain weight (g)

It is a good indicator to check the effect of the treatments on the grain yield of crop. Fertilizers especially integrated management of organic and inorganic sources with sustainable moisture availability significantly improved the grain size and weight. Data regarding to 1000-grain weight were given in Table III showed the significant effects of different tillage practices in both years of study. Significantly, higher1000-grain weight was recorded in deep tillage sown crop (283.15 g) which was statistically similar with those of conventional tilled crop (275. 64 g) that was also at par with those of minimum tillage sown crop (267.98 g). Statistically lower 1000-grain weight was noted in the maize crop sown by zero tillage (240. 31 g) during 2010. In 2011, significantly higher thousand grain weight was noted in T_4 which was followed by T_3 and lower was observed in T_1 treatments. Higher thousand grains weight inT_4 might be due to proper moisture availability and frequent availability of nutrients that resulted in bulky seeds. Moreover, the more bulky number of grains per cob and number of grain rows per cob may also resulted in heavier 1000-grain weight. These findings were supported by those of Zorita (2000). They noted the higher grain yield trend was shifted from deep tillage sown crop to zero tillage sown crop. Khan et al. (2007) concluded that deep tillage grown maize produced heavier 1000-grainweight as compared to conventional and zero tilled maize crop.

Significantly more thousand grains weight was obtained in PM_3 treatment (278.16 g) followed by PM_2 (268.71 g).The less thousand grains weight was recorded in PM_1 (253.44 g) where no poultry manure was applied. In 2011, PM showed the similar data trend as in 2010 (Table III).Higher 1000-grains weight inPM_3 treatments might be due to more crop growth rate, higher leaf area index with more chlorophyll contents due to integrated application of poultry manure and inorganic fertilizers which resulted in more formation of plant carbohydrates and ultimately heavier grains. Ayoolal and Makinde (2009) obtained higher 1000-grain yield in poultry manure plots and lower in synthetic fertilizers plots and in control. Garg and Bahla (2008) was reported that the higher thousand grains yield with the increased poultry manure amount which was might be due to balanced nutrients supply throughout the growth and development stages of the plant.

The significant difference in the year was might be due to difference in the climatic conditions in both years (Fig. I).Interactive effect of tillage practices and poultry manure during 2010 and2011 was significant with highest thousand grains weight was in $T_4 \times PM_3$ (292.88 g) that was statistically similar with those of $T_3 \times PM_3$ and $T_2 \times PM_3$ while the lowest thousand grain weight was observed in $T_1 \times PM_1$ as shown in Fig. I. As far as 2011 data are concerned, almost similar data fashion were noted as in 2010. Heavier grains were might be due to synergetic effect of deep tillage practices and poultry manure with more provision of nutrients and minerals to the maize plants.

Grain yield (Mg ha^{-1})

The data presented in Table III showed that the different tillage practice shad significantly affected the grain yield in both years of study. Significantly higher grain yield was in T_4 (8.01 Mg ha^{-1}) followed by T_3(7.75 Mg ha^{-1}) andT_2 (7.68 Mg ha^{-1}). T_1treatments produced the lower grain yield (6.37 Mg ha^{-1}) during 2010. In 2011, T_4 produced significantly higher grain yield than T_1 followed by T_3 andT_2 (Table III). The higher grain yield in T_4 treatments were might be due to the more moisture and nutrients availability from the deeper soil profiles throughout the growing season and plant enjoyed the lavish nutrients for growth and development. Moreover, the 1000-grain weight was also higher in T_4treatments as compared to other tillage crop which might also be resulted in good grain yield. The lower grain yield in T_1treatments could be due to unhealthy soil conditions for the plants. Furthermore, more soil mechanical impedance and more mechanical injury in T_1 treatments stopped the plant roots to go to deeper soil profiles for more nutrients and minerals. The experiment results of lower grain yield in T_1 treatments are in line with those of Hamza and Anderson (2005), Micucci and Taboada (2006) and Passioura (2002). They reported thathigher soil bulk density and more root penetration resistance may result in to lower grain yield. The experiment results are in accordance with those of Vetsch and Randall (2004).They reported that the deep tillage crop produced the more grain yield than the other till age practices (minimum tillage, zero tillage and strip tillage). Zorita (2000) concluded that chiselplough and mould board plough sown maize crop produced almost 90 % more grain yield than the zero tilled and shallow maize grain fields. Similarly, Marwart et al. (2007) concluded that conventional tillage crop produced more grain yield as compared to zero or reduced tillage crop. The experiment results are in contrary with those of Khan et al. (2009) reported that higher grain yield was in zero till age crop as compared to conventional and deep tillage crop. It might be due to different soil texture and structure.

Significantly more grain yield was recorded in PM_3treatments (7.92 Mg ha^{-1}) followed by PM_2 treatment (7.48 Mg ha^{-1}) and less grain yield was in PM_1 treatments (6.95 Mg ha^{-1}) during 2010. The same fashion of data was noted in the next year trial (2011) as shown in Table III. The data trend concluded that higher amount of poultry manure could produce more grain yield which was due to more provision of nitrogen and other balanced nutrients. The results of higher grain yield in the PM treatments are supported by Garg and Bahla (2008) and Ma et al.(1999) who noted that poultry manure may provide more sustainable nutrients as compare to no poultry manure treatments. In addition to, PM improved soil physico-chemical conditions i.e. soil cation exchange capacity and pH. Moreover, the poultry manure had lower C:N ratio than the other organic manures which allowed them to decompose easily with more nutrients availability. The experiment results are also in line with those of Shepherd and Withers (1999). Similarly, Boateng et al. (2006) reported that the poultry manure significantly increased the grain yield as compared to the inorganic fertilizers and farm yard manure which might be due to slow release of nutrients from the poultry manure.

The interaction of tillage practices and poultry manure was significant during the both growing seasons. Statistically maximum interactive grain yield was recorded in $T_4 \times PM_3$ that could not reach the level of significance with those of $T_2 \times PM_3$ during 2010 while in2011, almost similar data pattern was observed. These results are in accordance with those of Sistani et al. (2008). They observed a significant effect of different tillage systems and poultry manure on the grain yield of maize was observed. Year effect was found significant on the grain yield. These results are in line with those of Vetsch and Randall (2004). They reported that the weather significantly affected on the maize grain yield.

Conclusion

The study concludes that T_4(deep tillage) and PM_4 (@10 Mg ha^{-1}) significantly improved plant population, number of grains per cob, grain rows per cob, 1000-grains weight and maize crop grain yield during the both years of study. So that, the poultry manure should be used along with the synthetic fertilizers to sustain the soil fertility and productivity where the poultry manure is available. The farming community should include the deep tillage practice in their cropping system.

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