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IMPACT OF CROP RESIDUE, FETILIZER AND THEIR PLACEMENT TECHNIQUE ON YIELD AND RELATED TRAITS OF MAIZE (*Zea mays* L.)

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ABSTRACT

Crop residue incorporation is an environment friendly strategy which is becoming a common soil management practice for sustainability of soil fertility. To study the impact of various placement techniques of different crop residues (i.e. legume residue and wheat straw), fertilizer-N and their various combinations on maize crop; an experiment was conducted at New Developmental Research Farm of University of Agriculture, Peshawar, Khyber Pakthunkhwa. The crop residue/fertilizer was applied at three-placement depths i.e. surface, shallow (3 cm) and deep (6 cm) incorporation for evaluating its utilization efficiency by maize. Randomized complete block design in a split plot arrangement was used in the experiment. Placement depths of the residues/fertilizer showed inconsistent results and did not express significant differences for most of the observations. However, shallow incorporation of the treatments showed good results in terms of ears per plant, total aboveground biomass yield, grains per ear and grain yield. Recommended rate of N-fertilizer and mixture of half fertilizer and full rate of legume residues showed better performance than all other treatments. Maize showed better utilization of N-fertilizer and responded with best results in terms of 1000-grain weight, aboveground biomass and grain yield. Mixture of half fertilizer and legume residue increased performance of maize showing good results for ears per plant and grains per ear. Control (no residue/no fertilizer) showed poor results for almost all traits. While wheat straw amended treatments also had poor effect on the overall growth and development of maize.

Keywords: maize, crop residues, inorganic fertilizer, placement technique, yield.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops all over the world. It is also called “queen of cereals” as it can be grown throughout the year mainly due to its photo-thermo-insensitive character (Verma, 2011). For higher yield maize must be supplied with adequate nutrients particularly nitrogen, phosphorus and potassium (Iken and Amusa, 2004). Nitrogen (N) is a key element which plays a vital role in the overall growth and improves the yield attributes of most crops. Commercial fertilizer-N at 81.7 million tons (MT), accounts for almost half of all N reaching global croplands and supplies basic food needs for at least 4% of the population (Fixen and West, 2002). High costs of fertilizers have left the least developed countries in a menace due to the low fertility status of the soil (Arif *et al*., 2011). As an alternate solution the farmers can use the crop residues of the previously grown crops to overcome the problem of low soil fertility. Residue addition to the soil and the changes associated changes are important in planning cultural operations and developing appropriate soil management systems (Mbah and Nneji, 2011).

Farmers can improve their yield by adopting improved cultural and soil conservation practices. And crop residue placement is one of the conservation practices. Crop residues account for 37% of total crop N output, and of this 60% i.e., almost 4.2 million tones or 12% of total N, is not recycled and is used for other purposes or is lost from the system (Sheldrick *et al*., 2003). Crop residue recycling improves the overall attributes of soil by enhancing its quality fertility. Soil properties like soil moisture content, temperature, aggregate formation, bulk density, soil porosity and hydraulic conductivity are affected by residue management practices (Mandal *et al*., 2004). Residues of cultivated crops can significantly improve the physical, chemical and biological properties along with the overall quality of the soil (Kumar and Goh, 2000), and consequently result in better establishment of the crop. Nitrogen is available in the soil after mineralization of crop residues. Varco *et al*. (1993) reported that plant residue decomposition and hence short term N availability to plants, is increased if residues are incorporated into the soil rather than left on the soil surface. Kolawole and Tian, (2007) found that application of phosporus alone was not beneficial but when combined with crop residue it gave better results. Similarly straw placement will also allow rainwater to pass through, while at the same time reducing water droplet impact. The most beneficial effect of crop residue placement is the reduction of water runoff, evaporation (Singh and Singh, 1994) and soil erosion (Khatibu *et al*., 1984). Crop residues help in the reduction

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of weed infestation through competition and not allowing weed seeds the light often needed for germination (Hobbs *et al*., 2008), conserves soil moisture (Mullins *et al*., 1992) and regulates the soil temperature (Tindall *et al*., 1991).

Zero tillage without any crop residue drastically reduces yield (Govaerts *et al*., 2005). Direct planting into surface crop residue with reduced tillage methods is highly effective for control of erosion. However, crop yields may be lower than those from conventional tillage. The decrease in yield is sometimes attributed to the presence of toxic compounds produced during decomposition of surface residues (Cochran *et al*., 1977; Ellis *et al*., 1977; Pappendick and Miller, 1977). Sometimes the application of fertilizer N will partially alleviate such yield reductions (Cochran *et al*., 1977). Many investigators have found that surface managed crop residues decompose more slowly than incorporated residues, indicating that the N immobilization potential of surface residues is lower than that of residues mixed in the soil (Brown and Dickey, 1970).

Keeping in view the importance of crop residue/N-fertilizer and their placement methods, this project was designed (1) to determine the best placement technique for crop residues and fertilizer; and (2) to evaluate the response of maize to chemical fertilizer, legume residues, cereals residues and their different combinations.

MATERIALS AND METHODS

This study was conducted at New Developmental Farm (NDF) of University of Agriculture, Peshawar. The experimental site has continental climate and is located at 34^o N, 71.3^o E and at an altitude of 367 meters above sea level (Khan *et al*., in press). Experiment was carried out according to randomized complete block design with split-plot arrangements. The variety sown was Kisan. The experiment consisted of cereal (wheat straw), legume (berseem) residue and fertilizer-N. The effect of combination of wheat straw and berseem with fertilizer was also studied. Similarly the placement (distribution) of these crop materials was also included in the experiment. Placement treatments consisted of surface mulch, shallow (3 cm) and deep (6 cm) placement in the soil. Crop residue placements were allotted to main plots while crop residues/fertilizers were randomized in subplots. A subplot size of 5 m length and 2.8 m width was used with a row to row distance of 70 cm and the plots were replicated four times. Uniform cultural practices suiting the locality were followed for all experimental units. No pests or diseases were observed during the whole experimental period.

The following treatments were studied.

A. Placement (main plot)
P_1 Surface mulch
P_2 Shallow (3 cm) incorporation
P_3 Deep (6 cm) incorporation
B. Crop residue/fertilizer-N (subplot)
T_0 Control (no residue/no fertilizer)
T_1 Wheat straw (4000 kg ha^{-1})
T_2 Berseem (2000 kg ha^{-1})
T_3 Fertilizer-N (150 kg ha^{-1})
T_4 ½ straw + ½ berseem
T_5 Full straw + ½ fertilizer-N
T_6 Full berseem + ½ fertilizer-N

Data were recorded on number of ears per plant, number of grains per cob, thousand grain weight, grain yield and total aboveground biomass. For calculating number of ears per plant 10 representative plants were selected randomly and the ears in each plant were counted. For calculating number of grains per cob, grains from ten ears were removed. Grains were then counted and their sum was divided by 10 to get average grains per cob. Thousand grain weight data was recorded by weighing 1000 grains from each subplot. For recording total aboveground biomass, the whole sub plot was harvested stacked for uniform drying and then weighed. Similarly, for recording grain yield data, the two central rows in plots were harvested; the ears were husked, dried and threshed. Then total grain weight was recorded and converted into kg ha^{-1}.

Statistical analysis

All the data were statistically analyzed according to RCB design with split plot arrangements. The analysis of variance and F-test were employed to detect whether effects of treatments and the treatment interactions were significant or not. Least Significant Difference (LSD) test was also used for comparison among the treatments.

RESULTS AND DISCUSSIONS

Ears per plant

Number of ears per plant is one of the major yield components. Data obtained on number of ears per plant showed that different crop residues/fertilizer and their placement depth had significant effect on number of ears per plant (Table-1). Generally mixture of legume and fertilizer produced comparatively more ears per plant. Mixture of berseem and fertilizer resulted in greater 0.91 ears per plant followed by 0.89 ears per plant by mixture of fertilizer and wheat straw. While control (no residue/no fertilizer) and mixture of half berseem and half straw resulted in lower 0.73 and 0.75 ears per plant, respectively. Planned comparisons of means reveal that besides contrast between organic vs. inorganic treatments all other contrasts significantly varied from each other (Table-4). Considering the interaction of placement methods and crop residues/fertilizer, the data imply that the interaction was significant. More ears were produced by wheat straw, berseem residue and mixture of straw and fertilizer when they were shallow incorporated. While, N-fertilizer, mixture of half straw and half berseem and mixture of fertilizer and berseem produced greater number of ears per plant when they were deep incorporated. The reason for relatively more ears per plant under legume treatment amended with inorganic fertilizer could be the better quality of legume residue than cereal straw plus the easily available N from inorganic fertilizer. It seems likely that

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mixture of legume and fertilizer enriched the soil with other essential nutrients along with nitrogen and thus improved the texture and structure of soil providing excellent environment for the plants to develop reproductive organs (ears). The probable reason for fewer ears in control treatment might be the low fertility status of the plots leading to minimum ears formation.

Table-1. Number of ears per plant of maize as affected by placement of crop residues and fertilizer.

Treatments	Surface	Shallow	Deep	Mean
T_0 (Control)	0.74	0.70	0.74	0.73 d
T_1 (Wheat straw)	0.87	0.88	0.84	0.86 b
T_2 (Berseem residue)	0.72	0.90	0.77	0.80 c
T_3 (Fertilizer-N)	0.85	0.83	0.86	0.84 b
T_4 (½ WS + ½ BR)	0.77	0.73	0.75	0.75 d
T_5 (Full WS + ½ FN)	0.88	0.91	0.88	0.89 a
T_6 (Full BR + ½ FN)	0.91	0.91	0.92	0.91 a
Mean	0.82 b	0.84 a	0.82 b	

Means within columns followed by a common letter are not significantly different (P<0.05)
LSD (0.05) for placement 0.01
LSD (0.05) for treatment 0.02
LSD (0.05) for interaction **

Grains per cob

Number of grains per cob significantly contributes to the economic yield as well as represents the reproductive efficiency of any cereal crop. Data recorded on number of grains per cob (Table-2) suggested that various placement methods did not significantly affect number grains per cob in maize, while the effect of crop residues/fertilizer was significant. Addition of chemical fertilizer and its mixture with legumes produced greater number of grains per cob. Mixture of legume and fertilizer and sole addition of chemical fertilizer resulted in the highest 263 grains per cob. Control (no residue/no fertilizer) produced the least i.e., only 192 grains per cob. Planned comparisons of means Table revealed that the contrasts of control vs. rest and organic vs. inorganic were significant, while contrasts between other treatments were non-significant.

Table-2. Number of grains per cob of maize as affected by placement of crop residues and fertilizer.

Treatments	Surface	Shallow	Deep	Mean
T_0 (Control)	178	207	192	192 d
T_1 (Wheat straw)	231	225	221	226 bc
T_2 (Berseem residue)	224	247	251	241 ab
T_3 (Fertilizer-N)	253	283	250	262 a
T_4 (½ WS + ½ BR)	252	203	254	236 b
T_5 (Full WS + ½ FN)	216	220	186	208 cd
T_6 (Full BR + ½ FN)	266	277	254	266 a
Mean	232	238	230	

Means within columns followed by a common letter are not significantly different (P<0.05)
LSD (0.05) for placement ns
LSD (0.05) for treatment 193
LSD (0.05) for interaction *

(Table-4) Interaction of crop residues/fertilizer with their placement techniques was also significant. Greater number of grains per cob was observed when sole chemical fertilizer, mixture of straw and fertilizer and mixture of berseem and fertilizer were shallow incorporated into the soil. While shallow incorporation of mixture of straw and berseem produced lower number of grains per cob as compare to other placement depths. The higher fertility status of mixture of legume and fertilizer probably provided an excellent environment for the plants

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to grow and develop properly. These findings are in conformity with those of Kolawole and Tian (2007) who found that plant residues when combined with phosphate rock can improve the performance of maize. The plants grown under these treatments expressed their maximum genetic potential for grains formation. In addition the mineralization of legume residue throughout the growing period and readily availability of nitrogen from chemical fertilizer did not put the plants in nutrient stress at any stage and resulted in maximum grains production.

Thousand grain weight

Grain weight is also an important yield component that contributes to over all yield of maize. Grains become dominant sink at maturity stage and all the photo assimilates deposited in the grains give them weight. Analysis of variance of thousand-grain weight data revealed that surface placement; shallow incorporation or deep incorporation of residue/fertilizer had no significant effect on thousand-grain weight (Table-3). The addition of chemical N-fertilizer produced plants with heavier grains. Similar response was observed for plots where mixture of legume and fertilizer was applied. The sole application of chemical N-fertilizer resulted in 267.73 gm per thousand grains, followed by mixture of legume and half N-fertilizer, which resulted in 262.22 gm per thousand grains. In contrast, lighter grains of 242.2 gm per thousand grains were obtained from plots where mixture of straw and berseem was added. Planned comparisons of means could extract significance only for the contrasts of organic vs. inorganic and mixture (org) vs. mixture (org+inorg), while the other two contrasts were not significant Table-4. Interaction of the placement depths and crop residue/fertilizer also had no significant effect on thousand-grain weight. Comparatively, surface placement of the crop residues/fertilizer produced heavier grains, while their shallow incorporation resulted in lighter grains. The reason for low thousand-grain weight from shallow incorporation could be the greater number of ears per plant (Table-1), more plants at harvest (data not shown) and greater number of grains per cob (Table-2), which might have adversely affected thousand grain weight. In case of residue/fertilizer the heaviest grains were obtained from plots where N-fertilizer was added, while the lowest thousand-grain weight was observed in plots of control (no residue/no fertilizer). Mixture of half N-fertilizer and half legume also resulted in heavier grains. The reason could be that N-fertilizer and legume residue have higher nitrogen content than wheat straw or control treatments. Similarly they are easily decomposed and provide early availability of nitrogen and other nutrients to the crop. Therefore plots where fertilizer or mixture of fertilizer and legume were applied produced heavier grains due to the availability of mineralized nitrogen and other nutrients.

Table-3. Thousand grain weight (g) of maize as affected by placement of crop residues and fertilizer.

Treatments	Surface	Shallow	Deep	Mean
T_0 (Control)	253.80	249.39	239.94	247.72 bc
T_1 (Wheat straw)	262.90	257.94	244.19	255.01 abc
T_2(Berseem residue)	246.65	240.62	252.99	246.75 bc
T_3 (Fertilizer-N)	279.32	261.40	262.48	267.73 a
T_4 (½ WS + ½ BR)	247.98	233.75	244.92	242.22 c
T_5 (Full WS + ½ FN)	269.83	247.42	255.57	257.61 ab
T_6 (Full BR + ½ FN)	279.78	251.60	255.29	262.22 a
Mean	262.90	248.87	250.77	

Means within columns followed by a common letter are not significantly different (P<0.05)
LSD (0.05) for placement ns
LSD (0.05) for treatment 13.18
LSD (0.05) for interaction ns

Grain yield

Grain yield is the single most important goal and ultimate objective of any cereal crop. Grain yield was not significantly affected by different placement depths as shown in Table-5. Shallow incorporation of the residue/fertilizer produced greater grain yield, while their surface placement resulted in lower grain yield. These results can be justified by the fact that shallow incorporation of the treatments resulted in greater number of plants at harvest and greater aboveground biomass, thus producing greater grain yield. The effect of crop residue/fertilizer and their interaction with placement was significant. Generally the application of chemical fertilizer increased grain yields more than any other crop residue or its mixture with fertilizer. The sole addition of N-fertilizer produced maximum grain yield of 2658 kg ha^{-1}, followed by a yield of 2299 kg ha^{-1} produced by mixture of N-fertilizer and berseem. These results agree with the work done by Dyke *et al*. (1976) who showed that when N-fertilizer was added to soil with or without green manures the yield produced by the manured soil was considerably greater even when the nitrogen fertilizer was applied at above rates than optimum. While low grain yield of 1740 kg ha^{-1} was observed in plots of control (no residue/no

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fertilizer). Planned comparisons of means show that contrasts between control vs. rest and organic vs. inorganic were highly significant, while contrasts between cereal vs. legume and mixture (org) vs. mixture (inorg) were non-significant (Table-7). Considering interaction of placement depths and crop residues/fertilizer the data revealed that greater grain yield was recorded when N-fertilizer was shallow incorporated in the soil. Similar response was shown by mixture of straw and berseem and mixture of straw and fertilizer. While sole wheat straw and mixture of berseem and fertilizer resulted in high grain yield when they were surface placed and vice versa for deep incorporation. While sole legume resulted in lower grain yield when it was shallow incorporated.

Table-4. Planned comparisons of means for ears per plant, grains per cob and thousand grains weight with their statistical significance.

Treatments	Contrast	Ears plant^{-1}	Significance	Grains cob^{-1}	Significance	1000-GW (g)	Significance
Control	Control vs. Rest	0.73	**	192	**	247.72	ns
Rest		0.84		240		255.26	
Cereal	Cereal vs. Legume	0.86	**	226	ns	255.01	ns
Legume		0.80		241		246.75	
Organic	Org vs. inorg.	0.83	ns	234	**	250.88	**
Inorganic		0.84		262		267.73	
Mix. (org)	Mix.(org) vs. Mix.(org+inorg)	0.75	**	236	ns	242.22	**
Mix. (org + inorg)		0.90		237		259.91	

** = Significant at 0.01 level of probability, ns = Non-significant, GW stands for grain weight

Table-5. Grain yield (kg ha^{-1}) of maize as affected by placement of crop residues and fertilizer.

Treatments	Surface	Shallow	Deep	Mean
T_0 (Control)	1646	1804	1771	1740 c
T_1 (Wheat straw)	2289	1900	1898	2029 bc
T_2 (Berseem residue)	2377	1554	2514	2148 b
T_3 (Fertilizer-N)	2296	2952	2727	2658 a
T_4 (½ WS + ½ BR)	1943	2561	1927	2143 b
T_5 (Full WS+½ FN)	1798	2089	1957	1948 bc
T_6 (Full BR+½ FN)	2496	2322	2080	2299 ab
Mean	2121	2169	2125	

Means within columns followed by a common letter are not significantly different (P<0.05)
LSD (0.05) for placement ns
LSD (0.05) for treatment 380
LSD (0.05) for interaction *

Table-6. Total aboveground biomass (kg ha^{-1}) of maize as affected by placement of crop residues and fertilizer.

Treatments	Surface	Shallow	Deep	Mean
T_0 (Control)	7247	7768	7086	7367 ab
T_1 (Wheat straw)	6604	7314	5603	6507 b
T_2 (Berseem residue)	6373	6982	5807	6388 b
T_3 (Fertilizer-N)	6704	9298	8559	8187 a
T_4 (½ WS + ½ BR)	6414	6761	6038	6404 b
T_5 (Full WS + ½ FN)	6809	6947	5543	6433 b
T_6 (Full BR + ½ FN)	7504	9357	7348	8070 a
Mean	6808	7775	6569	

Means within columns followed by a common letter are not significantly different ($P<0.05$)
LSD (0.05) for placement ns
LSD (0.05) for treatment 1490
LSD (0.05) for interaction ns

Table-7. Planned comparisons of means for grain yield (kg ha^{-1}) and aboveground biomass (kg ha^{-1}) with their statistical significance.

Treatments	Contrast	Grain yield (kg ha^{-1})	Significance	Biomass (kg ha^{-1})	Significance
Control	Control vs. Rest	1740	**	7367	ns
Rest		2204		6998	
Cereal	Cereal vs. Legume	2029	ns	6507	ns
Legume		2148		6388	
Organic	Org vs. inorg.	2089	**	6447	**
Inorganic		2658		8187	
Mix. (org)	Mix.(org) vs. Mix.(org+inorg)	2143	ns	6404	ns
Mix. (org + inorg)		2124		7251	

** = Significant at 0.01 level of probability, ns = Non-significant

Aboveground biomass

Total aboveground biomass is an important character that contributes to the final yield along with the economic yield. Aboveground biomass data showed that different residue/fertilizer incorporation technique had no significant effect on this trait of maize, while the residues/fertilizer significantly affected aboveground biomass (Table-6). Shallow incorporation of the treatments comparatively produced greater aboveground biomass, while their deep incorporation resulted in low aboveground biomass. The greater aboveground biomass may be attributed to the greater number of plants at harvest, taller plants under shallow incorporation while, in case of deep incorporation the dwarfness of the plants and less number of plants at harvest (data not shown) might have reduced the overall aboveground biomass of plants. Generally the addition of chemical fertilizer and its mixture with legume residue produced plants with greater aboveground biomass than other residues/fertilizer. The sole application of N-fertilizer produced plants with a greater aboveground biomass (8187 kg ha^{-1}), followed by mixture of berseem and fertilizer for which the aboveground biomass was 8070 kg ha^{-1}. On the other hand the highest aboveground biomass was recorded in plots of chemical fertilizer and its mixture with legume residue, while aboveground biomass of the rest of treatments did not vary significantly. The highest aboveground biomass yield from N-fertilizer could be the greater number of emerged plants; tallest plants and the maximum number of plants at harvest (data not shown for these parameters) along with the greater fertility status of the plots. It confirms that N-fertilizer enhances the vegetative growth of the plants. While minimum aboveground biomass 6388 kg ha^{-1} was observed in legume residue incorporated plots which was not significantly different from most of the rest of treatments. Planned comparisons of means revealed that among all the contrasts only contrast between organic vs. inorganic fertilizer was significant (Table-7). Interaction of crop residues/fertilizer with their placement technique also had no significant effect on the aboveground biomass of maize. The finding of this trial are in conformity with those of Arif *et al*. (2011) who found that addition of crop residues can improve grain weight, number of grains per ear, grain and biological yields in comparison with no residues added plots.

CONCLUSIONS

The findings of this trial suggest that crop residues can partially (if not fully) compensate for the low fertility status of the agricultural soils caused due to high cost of chemical fertilizer. A combination of chemical fertilizer and crop residues especially legume residues can be termed as an ideal technique to maintain the fertility of soil in both short and long terms. Although chemical fertilizer resulted in best results, it seems logical to conclude that a combination of legume residues with it will have more benefits in the long run due to slow decomposition of residues which will ensure nutrients availability in the following years.

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