

Tillage and crop residue effects in rainfed pearl millet (*Pennisetum glaucum*) in conjunction with sulphur fertilization under pearl millet–Indian mustard (*Brassica juncea*) cropping system

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ABSTRACT

A field experiment was conducted during rainy (*khari*) seasons of 2013 and 2014 to find out the impact of tillage, crop residue and sulphur fertilization on growth, productivity and economics of pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz.]. Five tillage and residue management practices i.e. conventional tillage (CT) with 0, 2 and 4 t/ha crop residue; zero tillage (ZT) with 2 and 4 t/ha crop residue were allocated to main plots and four sulphur levels (0, 15, 30 and 45 kg S/ha) in sub-plots. Conventional tillage with 4 t/ha residue gave significantly higher growth parameters (plant height, dry-matter accumulation and leaf area index) and SPAD value at various growth stages of crop. This treatment also improved yield attributes of pearl millet, viz. length of earhead, grains weight/earhead and 1,000-grains weight and produced 24.3 and 16.6% higher grain and stover yields over CT without residue, respectively. The highest net returns ($31.5 \times 10^3 \text{ ₹/ha}$) and Benefit: cost ratio (1.69) were computed in ZT with 4 and 2 t/ha residue, respectively. Results also revealed that increasing levels of sulphur up to 30 kg/ha significantly increased growth parameters, SPAD value, yield attributes and yield of pearl millet as compared to control. Application of 30 kg S/ha resulted in 15.6 and 20.4% higher grain and protein yield over the control, respectively. Furthermore, the highest net returns ($31.5 \times 10^3 \text{ ₹/ha}$) and benefit: cost ratio (1.50) were also fetched with 30 kg S/ha.

Key words : Economics, Growth, Pearl millet, Residue, Sulphur, Tillage, Yield

Pearl millet is a staple diet of rural population and also an important fodder crop in arid and semi-arid regions of India. The realized productivity of pearl millet is below its potential. The main reasons of poor crop yield are low moisture availability to crop during growing season and lack of proper nutrient management. As the moisture is the most limiting factor in the rainfed farming and the rainfall is the only source of water for these lands, *in-situ* rain water conservation in the root zone is perhaps the most cost-effective means of increasing moisture availability to the plants. Water conservation is considered a key element of conservation agriculture, especially in dryland areas exposed to erratic and unreliable rainfall (Serraj and

Siddique, 2012). In recent years, interest of farmers in conservation tillage has also increased because of escalation of fuel prices and production costs. Various on farm studies revealed little or no difference in yields of crops under zero-till system, compared with conventional tillage (Krishna and Veetil, 2014). However, yield variability with zero-tillage still remains a major concern among farmers. Zero-tillage practices are more advantageous when crop residue is retained on soil surface. Use of crop residue as mulch is a viable approach to retain soil moisture and nutrients under such situations because mulch is poor conductor of heat that effectively moderates soil temperature, maintain soil moisture and increase soil fertility but crop residues have competing uses like fodder in rainfed areas because of dominance of livestock. Further, costs are also incurred in their application. Therefore, it is necessary that a suitable amount of crop residue should be applied to enhance crop productivity in a cost-effective manner.

Deficiency of sulphur is wide spread (41%) in India particularly in semi-arid tropics region (Sahrawat *et al.*,

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2007). Sulphur is best known for its role in the synthesis of proteins, oils, vitamins and flavoured compounds in plants. Sulphur application in deficient soils significantly increased pearl millet yield in the on-farm studies (Gupta and Jain, 2008). However, for sustained increase in productivity of rainfed areas, soil and water conservation measures need to be integrated with plant nutrition, and choice of crops and their management. Keeping these aspects in view an experiment was undertaken to study the effect of tillage, crop residue and sulphur on growth, productivity and profitability of pearl millet under pearl millet-Indian mustard cropping system.

MATERIALS AND METHODS

A field experiment was conducted at the Research Farm of Indian Agricultural Research Institute, New Delhi during the rainy (*kharif*) season of 2013 and 2014. The experimental site is situated at (28° 38' 23" N and 77° 09' 27" E and of 228.6 m above mean sea-level) in a semi-arid subtropical climatic belt, with annual maximum temperature as high as 45°C in summers and minimum temperature as low as 1°C in winters. The total rainfall received during the cropping season of 2013 and 2014 was 944 and 270 mm, respectively. The soil is sandy loam in texture, slightly alkaline in reaction (*pH* 7.8), low in organic carbon (4.5 g/kg) and available nitrogen (139.7 kg/ha) and medium in available P (15.2 kg/ha) and K (178.8 kg/ha) and deficient in available S (8.8 mg/kg soil).

The fixed layout experiment was laid out in split-plot design with 3 replications having five tillage and residue management practices to pearl millet and mustard in the main-plots, (conventional tillage (CT) without residue; CT with 2 and 4 t/ha residue; zero tillage (ZT) with 2 and 4 t/ha residue), and 4 sulphur levels (0, 15, 30 and 45 kg S/ha) in the sub-plots. In conventional tillage, field was prepared with a disc plough followed by two pass of a disc harrow and planking in the last to have a uniform seed bed of fine tilth. No tillage operation was carried out in zero-tilled plot. Crop residues of previous season mustard were applied by spreading the material uniformly on the field just after sowing. Sulphur was applied through agriculture grade gypsum containing 13% S at the time of field preparation as per treatment in both the seasons. Pearl millet ('Pusa 443') was sown on 12 and 20 July 2013 and 2014, respectively with a spacing of 45 cm × 15 cm. Uniform dose of N, P₂O₅ and K₂O @ 60–40–30 kg/ha were applied. Entire phosphorus and potassium were applied as basal through di-ammonium phosphate (DAP) and muriate of potash, respectively at the time of sowing, whereas N was applied in 2 equal split through urea at sowing and 25–30 DAS. In zero-tilled plots weeds were managed by glyphosate @ 0.1% before sowing and atrazine @ 0.5 kg

a.i./ha as pre-emergence. Thinning and gap filling were done at 20 days after sowing (DAS) to maintain the uniform plant stand. Crop was not irrigated in both years of experimentation and it was not affected by the incidence of pest and diseases.

Leaf chlorophyll concentration of the upper most fully expanded leaves was assessed with a portable chlorophyll meter (SPAD-502 Minolta, Tokyo, Japan) and was expressed in arbitrary absorbance (or SPAD) values. All chlorophyll meter readings were taken midway between the stalk and the tip of the leaf. In addition, leaf area was measured with a leaf area meter (LICOR-3000, Linclon, USA). The crop was harvested from the net plots. Grain and stover yield was expressed at 12% and 15% moisture level, respectively. Protein content in grain was worked out by multiplying the nitrogen content in grain with the factor 6.25. Protein yield (kg/ha) was calculated by multiplying the protein content with grain yield. The economics was computed using prevailing prices of inputs and outputs. Benefit: cost ratio was calculated by dividing net returns by cost of cultivation. Data obtained from various studies were statistically analyzed in split-plot design using the technique of analysis of variance (ANOVA). The differences between the treatment means were tested as to their statistical significance with appropriate critical difference (CD) value at 5% level of probability Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters

Tillage and crop residue had significant effect on plant height, dry matter accumulation, leaf area index and SPAD value at various stages of crop growth (Table 1). Tallest plants were recorded at harvest under conventional tillage (CT) with 4 t/ha residue which was statistically identical to zero tillage (ZT) with same residue level. Dry-matter accumulation was less at early growth stages, but it accelerated tremendously at peak growth and plant development (60 DAS and at harvest) stage. Significantly maximum dry-matter accumulation at harvest of crop was recorded in CT with 4 t/ha residue, which was 26.0% higher over CT without residue. Similar trend was observed in leaf area index. Higher SPAD value at 60 days after sowing (DAS) was in CT with 4 t/ha residue, remained at par with all other treatments except CT without residue. CT and ZT were statistically similar at same residue level. The improvement in growth parameters of pearl millet ascribed to higher moisture in residue applied plots as residue cover conserved soil moisture (Mulumba and Lal, 2008) and continuously provided to the crops. Adequate availability of moisture to plants resulted in cell turgidity and eventually high meristematic activity, leading to more foliage

development, greater photosynthetic activity and consequently higher growth and development. Moreover, enhanced the nutrient supply through residue decomposition coupled with favorable moisture condition created conducive environment for plant growth and development (Dass *et al.*, 2013).

All growth parameters, viz. plant height, dry matter accumulation; LAI and SPAD value were also increased with each successive level of sulphur. In most of the growth stages, maximum values of these parameters were observed at 45 kg S/ha, which were significantly higher than the control, but remained at par with 30 kg S/ha. This may be ascribed to the role of S in plant metabolic activity, which may have led to the increased in photosynthesis. It is quite obvious that the continued and balanced supply of nutrients right from early stage of growth resulted in vigorous plant growth and higher leaf area, which eventually caused increase in dry-matter accumulation. Sulphur supply also increased the concentrations of N in leaves, which enhances the chlorophyll content resulted high SPAD value. Pagani and Echeverría (2012) also reported higher SPAD value with sulphur fertilization.

Yield attributes and yield

Yield attributes, viz. length of earhead, grain weight/earhead and 1,000-grains weight were significantly the highest under CT with thick residue cover (4 t/ha) followed by ZT with same residue than CT without residue (Table 2). The favourable effect of crop residue on growth through adequate supply of moisture, leading to greater nutrient uptake, efficient partitioning of metabolites and

adequate accumulation and translocation of photosynthates resulted in improved yield attributes (Sinha, 2015). Similarly, grain and stover yield varied significantly with tillage and residue management practices. CT with 4 and 2 t/ha residue showed 24.3 and 14.1% higher grain yield over CT without residue. Under ZT marginally lower grain and stover yields (but not statistical significant) were recorded than CT at corresponding residue levels. Similar trend was observed in stover yield. The increase in grain yield with 4 t/ha crop residue under both tillage systems might be owing to better availability of moisture and nutrients, which led to increase in growth and yield attributes and finally the grain yield. The response of residue management was noticed in both the tillage systems. This could be attributed to residue effect on soil surface characteristics. It is likely that applying the same amount of residue in both tillage regimes have assisted the soil with the same benefits in terms of developing favourable soil environment. Higher yield with residue application has been also reported by Saha *et al.* (2010).

Yield attributes of pearl millet (length of earhead and grain weight per earhead) were also influenced significantly with sulphur fertilization. Highest values of these traits were recorded with 45 kg S/ha, but it was found statistically at par with 30 kg S/ha. Similarly, increasing levels of sulphur significantly increased the grain and stover yield of pearl millet (Table 2). Application of sulphur up to 30 kg/ha to pearl millet significantly enhanced the grain and stover yield by 15.6 and 14.3%, respectively over control. Further increased level of sulphur did not influence yield attributes and yield. Sulphur plays a vital role in im-

Table 1. Effect of tillage, crop residue and sulphur levels on growth parameters of pearl millet (mean data of 2 years)

Treatment	Plant height (cm)			Dry-matter accumulation			Leaf-area index		SPAD value	
	30 DAS	60 DAS	Harvest	(g/plant)			30 DAS	60 DAS	30 DAS	60 DAS
				30 DAS	60 DAS	Harvest				
<i>Tillage and crop residue</i>										
CT without residue	54.8	206.6	218.3	11.4	55.0	75.3	2.06	3.93	45.8	50.0
CT with 2 t/ha residue	57.6	226.2	238.7	12.4	63.2	87.3	2.35	4.58	47.1	52.1
CT with 4 t/ha residue	59.2	238.5	252.1	13.4	68.3	94.9	2.53	4.99	49.2	53.7
ZT with 2 t/ha residue	56.5	219.1	232.1	12.0	60.0	82.2	2.23	4.32	45.2	48.3
ZT with 4 t/ha residue	58.8	235.1	249.0	13.0	66.4	91.6	2.44	4.80	47.4	50.8
SEm±	1.3	4.7	4.6	0.2	1.7	2.0	0.05	0.14	0.8	0.8
CD (P=0.05)	NS	15.4	14.9	0.8	5.4	6.6	0.16	0.46	NS	2.5
<i>Sulphur level (kg/ha)</i>										
0	55.3	211.9	224.4	11.9	56.8	77.1	2.20	4.02	45.6	48.4
15	57.4	223.6	236.1	12.3	61.5	86.1	2.31	4.41	46.7	50.6
30	58.4	230.9	244.0	12.6	65.1	89.9	2.37	4.76	47.6	52.1
45	58.3	234.0	247.7	12.9	66.8	92.0	2.41	4.90	47.8	52.6
SEm±	0.9	2.8	3.0	0.1	1.1	1.3	0.03	0.09	0.5	0.8
CD (P=0.05)	NS	8.1	8.7	0.4	3.3	3.9	0.09	0.27	1.4	2.2

CT, conventional tillage; ZT, zero tillage; DAS, days after sowing

proving vegetative structure for nutrient absorption, increasing sink strength through development of reproductive structures by production of assimilates to fill economically important sink (Malhi *et al.*, 2007). Since the experimental soil was deficient in available sulphur (8.8 mg/kg), so application of sulphur to soil increases the availability of $\text{SO}_4\text{-S}$ in soil (Gupta and Jain, 2008) which may have helped the crop to achieve better growth and yield. Furthermore, yields attributing character shown highly positive correlation (R^2 0.93 to 0.97) with grain yield as evidenced from the Figure 1, which ultimately resulted in higher grain yield in different treatments. The results are in close conformity with findings of Singh and Bhadoria (2014).

Protein content

Pearl millet planted under ZT with 4 t/ha crop residue

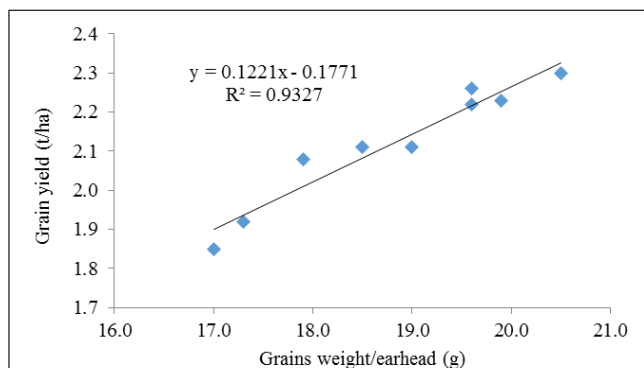
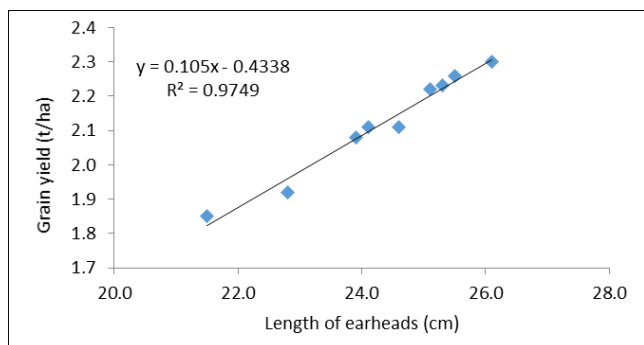
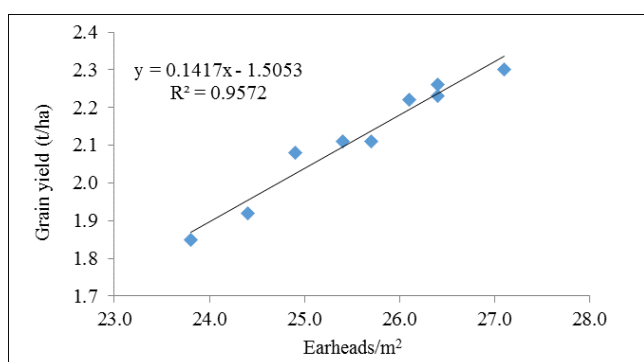


Fig. 1. Relationship between yield and yield attributes in pearl millet

recorded significantly highest protein content (11.1 per cent) and protein yield (250 kg/ha) than CT without residue but remained statistically similar to CT with same residue (Figure 2). Increased protein content in grain attributed to increased availability of nitrogen in the soil due to decomposition of crop residue. Higher nitrogen in seed is directly responsible for higher protein because it is a primary component of amino acids which constitute the basis of protein.

Increasing levels of sulphur up to 30 kg/ha, significantly enhanced the protein content of pearl millet while

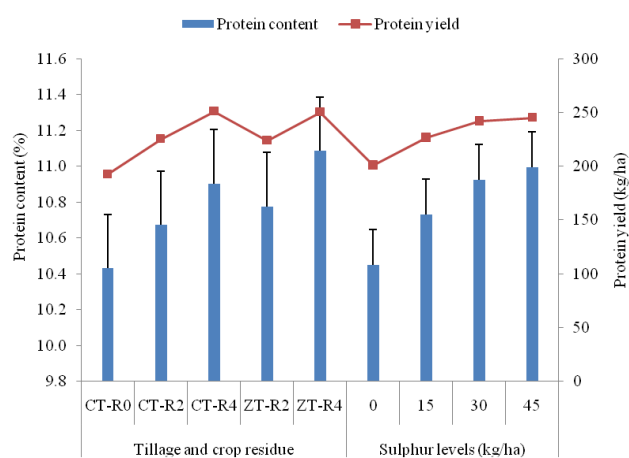


Fig. 2. Protein content and protein yield of pearl millet as influenced by tillage, crop residue and sulphur levels. R0, R2 and R4 indicates crop residue @ 0, 2 and 4 t/ha, respectively. Bar represents $CD_{0.05}$

protein yield increased up to 45 kg S/ha. The magnitude of increase in protein yield was 21.9% over control. Association of higher protein content with sulphur fertilization might be due to role of S in essential amino acids (cystine, cysteine and methionine). Other reason could be positive interaction between S and N (Jamal *et al.*, 2010) that led to higher availability of N resulted higher protein content. Higher grain yield and protein content led to higher protein yield. As protein yield is a function of protein content and grain yield.

Economics

Cost of cultivation of pearl millet crop under different tillage and residue management practices varied from minimum with ZT with 2 t/ha residue to maximum under CT with 4 t/ha residue (Table 2). Similarly, maximum net returns were recorded under ZT with 4 t/ha residue and lowest under CT without residue. While highest benefit: cost ratio was found under ZT with 2 t/ha residue (Table 2). Low cost of cultivation in ZT treatments mainly due to reduction in cost of land preparation and manual weed

Table 2. Effect of tillage, crop residue and sulphur levels on yield attributes, yield and economics of pearl millet (mean data of 2 years)

Treatment	Earheads/ m ²	Length of earhead (cm)	Grains weight/ earhead (g)	1,000- grains weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Cost of cultivation (× 10 ³ ₹/ha)	Net returns (× 10 ³ ₹/ha)	Benefit: cost ratio
<i>Tillage and crop residue</i>										
CT without residue	23.8	21.5	17.0	7.9	1.85	6.51	22.08	18.5	24.7	1.34
CT with 2 t/ha residue	25.7	24.6	19.0	8.4	2.11	7.20	22.71	21.4	27.3	1.28
CT with 4 t/ha residue	27.1	26.1	20.5	8.7	2.30	7.59	23.28	23.8	28.5	1.20
ZT with 2 t/ha residue	24.9	23.9	17.9	8.1	2.08	7.08	22.73	17.8	30.1	1.69
ZT with 4 t/ha residue	26.4	25.5	19.6	8.6	2.26	7.58	23.06	20.2	31.5	1.56
SEm±	0.7	0.6	0.4	0.1	0.05	0.18	0.17		1.1	0.06
CD (P=0.05)	NS	2.1	1.2	0.4	0.15	0.59	0.55		3.7	0.19
<i>Sulphur level (kg/ha)</i>										
0	24.4	22.8	17.3	8.1	1.92	6.57	22.66	19.7	24.6	1.26
15	25.4	24.1	18.5	8.4	2.11	7.10	22.88	20.3	28.1	1.40
30	26.1	25.1	19.6	8.4	2.22	7.51	22.81	20.6	30.4	1.50
45	26.4	25.3	19.9	8.5	2.23	7.59	22.74	20.9	30.5	1.48
SEm±	0.5	0.5	0.3	0.1	0.04	0.13	0.23		0.8	0.04
CD (P=0.05)	1.4	1.5	0.8	0.3	0.11	0.37	NS		2.3	0.11

CT, conventional tillage; ZT, zero tillage

control. Higher net returns under ZT with 4 t/ha crop residue due to more returns from higher yield as compared to cost involved under this treatment. Lower benefit: cost ratio under ZT with 4 t/ha crop residue in comparison to 2 t/ha crop residue was mainly attributed due to lower returns from residue in comparison to cost involved.

Application of 45 kg and 30 kg S/ha remained at par with each other and fetched significantly higher net returns and benefit: cost ratio. This is because of cost involved under treatment was comparatively lower than its additional returns. Since, gypsum is considered as a cheapest source of sulphur. Similar findings were also reported by Gupta and Jain (2008).

On the basis of 2 years experimentation, it can be concluded that planting of pearl millet under zero tillage with 4 t/ha crop residue along with 30 kg S/ha through gypsum could be recommended for realizing higher productivity and profitability under rainfed conditions.

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