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Performance of Zero-till Bio-mulching on Different Pulses under Maize-legume Sequence

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ABSTRACT

Background: After harvesting of *kharif* crops, lack of sufficient soil moisture availability limit the cultivation of *rabi* crops in the Birbhum district of West Bengal. So a huge area remains fallow during the *rabi* season mainly because of infrastructure to harvest and to utilize the bountiful rains of the monsoon. So, agronomic measures to conserve the soil moisture are very suitable for the region because of their low cost and capability to reduce soil erosion. In this region, maize stalk are not used as fodder for animals and are usually burnt or kept outside the field. Similarly, during rainy season, there is plenty of water hyacinth and paddy straw found around cultivated areas. Retention of crop residues and weed biomass on the soil surface in combination with zero tillage initiates process that lead to improve soil quality and overall enhancement of resource use efficiency.

Methods: The trials were conducted for consecutive two years (2017-18 and 2018-19) in split plot design with three main plot treatments as cropping system after Maize, *viz,* i) Maize-chickpea (CS_1) ii) Maize-lentil (CS_2) iii) Maize-lathyrus (CS_3); with five sub-plot treatments as mulching i) No-mulching (Residue Removal) (M_0) ii) *In-situ* Maize stalk mulching (M_1) iii) *In-situ* maize stalk mulch + Water hyacinth (5 t/ha) (M_2) iv) *In-situ* maize stalk mulch + Paddy straw (5 t/ha) (M_3) v) *In-situ* maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw (2.5 t/ha) (M_4) but the individual *rabi* crop's data were analyzed in randomized block design (RBD) as the individual crops have different growth characteristics.

Result: Experiments result revealed that mulching with M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha) is the best practice for growing pulses under zero-till condition after Maize in Maize-legume cropping system. Growing of pulses in different cropping system under zero-till condition not only will increase the cropping intensity and production of pulses in the country but also will increase the fertility of the soil.

Key words: Bio-mulching, Cropping system, Maize-legume sequence, Zero-till.

INTRODUCTION

Presently, India is producing 19.78 mt of total pulse from 25.21 mha with a productivity of 785 kg/ha (Imbasekar, 2014). In the world, India is the largest producer and consumer of pulses, accounting for about 25% of global production, 27% of consumption and 14% of the world importer (Shukla and Mishra, 2018). For reducing import of pulses we need to boost the pulse production through various ways. A total of 3.2 mt of additional pulses can be produced by India extending pulses area to rainfed rice/ maize fallow lands or replacing low productive crops and summer fallows (Imbasekar, 2014). Maize is cultivated in sequence with different field crops (including various pulses) under various agro-ecological situation of India, as it has a wide adaptability and compatibility under diverse soil and agro-climatic conditions. Hence, it is considered as one of the potential driver crops under different diversification situation. In dry region like Birbhum district of West Bengal, Maize is one of the most important cereal crops during *kharif* season and most of the land remains fallow after the *kharif* crops. So, pulses as a low water demanding crop can be grown economically without providing any extra irrigation.

This region generally receives enough amount of rainfall in monsoon, however due to erratic distribution of rainfall resulted in frequent occurrence of moisture stress in dry season. The average rainfall of the state estimate around 175 cm, from which maximum amount is lost through runoff. In West Bengal, more than 80% of annual rainfall is received during the month of May to October and rest of the months receives very scanty amount of rainfall, which makes insufficient soil moisture for growing any other crops in West Bengal without irrigation. Lack of irrigation facilities further makes it more complex for providing any supplemental irrigation. May to October is mainly the water surplus period, while November to April falls under water deficit period (Saha *et al*., 2007) and again tilling the soil after *kharif* crop results in loss of conserved moisture. Thus, zero tillage is a viable option and zero tillage has also reported to conserve soil moisture, improve soil health and especially during dry season (Bhagat and Archarya, 1987). Zero tillage offers the benefit of retaining surface residue and reduces soil water

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losses (Johnston *et al*., 2002; Ghosh *et al*., 2010). In addition to zero tillage mulching could conserve residual soil moisture to be utilized by a winter crop in an efficient manner (Franzen *et al.,* 1994; Moitra *et al*., 1996; Sarkar *et al*., 2007). Crop residue on soil surface form a barrier to water loss by evaporation and increase the amount of moisture store in the plant root zone and available to the crop.

Hence, present work has been formulated with mulching as one of the suitable moisture conservation technique for cultivating a *rabi* pulse crops after maize under zero tillage to evaluate the suitability under such dry land situation.

MATERIALS AND METHODS

Field experiments were conducted at the experimental farm of Institute of Agriculture, Visva-bharati for consecutive two years i.e. 2017-18 and 2018-19. The trials were conducted in split plot design with three main plot treatments as cropping system after Maize, *viz,* i) Maize-chickpea (CS_1) ii) Maize-lentil (CS_2) iii) Maize-lathyrus (CS_3); with five sub-plot treatments as mulching i) No-mulching (Residue Removal) (M_0) ii) *In-situ* Maize stalk mulching (M_1) iii) *In-situ* maize stalk mulch + Water hyacinth (5 t/ha) (M_2) iv) *In-situ* maize stalk mulch + Paddy straw (5 t/ha) (M_3) v) *In-situ* maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw (2.5 t/ha) (M_4) but the individual rabi crop's data were analyzed in randomized block design (RBD) as the individual crops have different growth characteristics. The pooled data of the experiments were generated by making average of 2017-18 and 2018-19 data and then the difference between the treatment mean were tested to their statistical significance with appropriate critical difference (C.D) value at 5% level of probability (Gomez and Gomez, 1984). The maize was sown during *kharif* season with all the recommended agronomic practices. The bio-mulche of water hyacinth was collected from nearby water bodies and paddy straw was collected from nearby fields, which were left in the fields after harvest of paddy. The bio-mulches were weighed and applied as mulch in between the row of standing maize 20 days before the harvest of maize as per the treatment requirement. After the harvest of maize, furrows were opened using a manual furrow opener by pushing the mulches on the side of maize rows to sow the *rabi* crops. The recommended doses of fertilizers and pulse seeds were placed in the furrows and covered with soil and the mulch materials were adjusted to cover the surface. Pendimethalin 30% EC at the rate of 4 ml/liter was applied to clean the field 1 day after sowing of *rabi* crops. After the germination of seeds, the maize stalk were cut and spread all over the field just above the mulching as per the treatment requirement to cover the soil surface. Plant growth parameters were recorded for Plant height (cm), dry matter accumulation per plant. The yield parameters harvest index and grain yield were primarily taken on individual plot basis and later on converted into kg per hectare. The system productivity for cropping system were calculated by adding the yield of each crop in a cropping system divided by duration of respective crops and were expressed in kg/ha/day and Maize equivalent yield (MEY) was calculated by multiplying yield of *rabi* crops (chickpea, lentil and lathyrus) with their respective price and divided by the market prize of maize. For estimation MEY the pooled yield of maize was taken 4666 kg and Prices of crops were taken maize Rs 17.6/kg, chickpea Rs 46.2/kg, Lentil Rs 44.75/kg and lathyrus Rs 35/kg respectively. The mean monthly total rainfall (mm) and pan evaporation (mm) for both the year was shown in Fig 1.

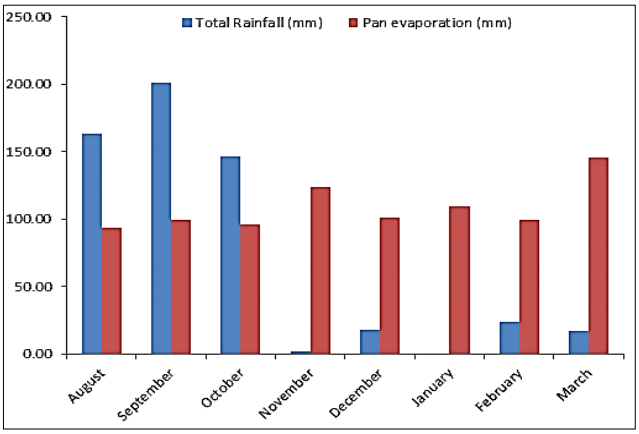


Fig 1: Average weather parameters during the cropping year 2017-18 and 2018-19.

RESULTS AND DISCUSSION

Plant growth parameters

In chickpea, lentil and lathyrus significantly taller plants were was recorded under M_3- In-situ maize stalk mulch + Paddy straw (5 t/ha) as compared to M_0- No mulch (residue removal) and M_1- *In-situ* maize stalk mulch (MSM) followed by M_4- *In-situ* maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw(2.5 t/ha) and M_2- *In-situ* maize stalk mulch + Water hyacinth (5 t/ha). In chickpea, lentil and lathyrus

Table 1: Effect of mulches on plant height (cm) of Chickpea, Lentil and Lathyrus (Pooled mean).

Mulches	Chickpea	Lentil	Lathyrus
M_0- No mulch (residue removal)	23.39	22.10	23.80
M_1- *In-situ* maize stalk mulch (MSM)	26.06	25.87	27.12
M_2- *In-situ* maize stalk mulch + Water hyacinth (5 t/ha)	29.57	27.28	30.52
M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha)	32.09	29.75	31.83
M_4- *In-situ* maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw (2.5 t/ha)	30.57	27.50	30.56
SE (m)±	1.07	1.37	1.08
CD (*P*=0.05)	3.28	4.22	3.33

significantly taller plants were recorded 32.09 cm, 29.75 cm and 31.83 cm respectively as in Table 1.

Significant results of mulching on plant height were found which might be due to higher moisture available in soil that leading to enhanced crop growth rate. Liasu and Achakzai (2007) reported that mulching with *Tithnia diversiflia* leaves and fertilizer application together promoted the growth (including plant height) and development and Pervaiz *et al*. (2009) reported that plant height was higher due to mulch application.

Significant effect of mulches was recorded on biomass accumulation in all the crops in M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha) as compared to other mulches. The biomass accumulation was highest in mulching plots over control and highest biomass accumulation was recorded under M_3- In-situ maize stalk mulch + Paddy straw (5 t/ha) in all the crops as in Table 2. This can be attributed to the improved water availability to the crop resulting from more efficient moisture conserving ability of the mulching compared to no mulch. Mulching enhanced soil moisture conservation and nitrogen addition from the mulched biomass might have improved nutrient supply, and thus resulted in better growth and dry matter production (Sharma *et al*., 2010). This might be due to higher plant height and leaf area due to organic mulching supported by the findings of Patil *et al*. (2011), Reddy *et al*. (2016). Mulching reduced the soil temperature at 0-10 cm of soil depth, it also reduces soil evaporation and increase dry matter accumulation during the growth stage reported by Bu *et al*. (2013); Prasad *et al*. (2014); Marwein and Ray (2018). The availability of high soil moisture reduces stomatal closure; which induces the openings of the pathways for the exchange of water, carbon dioxide and oxygen, resulting in increases in photosynthetic rate and which ultimately add the dry matter production (Madhu and Hatfield, 2014).

Yield parameters

In all the crops, significant influence of treatment on harvest index recorded due to mulches. Higher harvest index was obtained under M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha) as compared to M_0- No mulch (residue removal) and M_1- *In-situ* maize stalk mulch (MSM) followed by M_4- In-situ maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw (2.5 t/ha). The harvest index recorded under M_3- In-situ maize stalk mulch + Paddy straw (5 t/ha) are 19.21%, 26.38% and 18.39% higher as compared to M_0- No mulch (residue removal) in chickpea, lentil and lathyrus respectively (Table 3). Similarly the highest seed yield was recorded from M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha) in all the crops (yield) in chickpea, lentil and lathyrus are 1437 kg/ha, 975 kg/ha and 1526 kg/ha, respectively (Table 4). Higher seed yield might be due to combined use of maize stalk mulch and paddy straw/water hyacinth or combination of both that enhance the inherent moisture retention capacity as well as nutrient supplying capacity of the soil, which in turn improved seed yield. This could be due to addition of crop residue and subsequent decomposition released nutrient that helped in increasing the yield character of all the crops leading to their higher yield and better harvest index as compared to no mulch (Liu *et al*., 2002; Karunakaran and Behera, 2013; Reddy *et al*., 2016). Das *et al*. (2003) reported similar result in rice- wheat cropping system attributed to the ability of plant to absorb the adequate soil moisture and nutrients.

Significant effect of cropping systems and mulches was evident on maize equivalent yield (MEY) and system productivity. The highest MEY and system productivity was recorded in maize-chickpea cropping system (7566 kg/ha and 34.71 kg/ha/day) as compared to other two cropping systems (Table 5). There was 10.72% and 13.28% higher MEY and System productivity in maize-chickpea than maize-

Table 2: Effect of mulches on dry matter (g/plant) of chickpea, lentil and lathyrus (Pooled mean).

Mulches	Chickpea	Lentil	Lathyrus
M_0- No mulch (residue removal)	1.69	1.35	1.96
M_1- *In-situ* maize stalk mulch (MSM)	2.03	1.67	2.43
M_2- *In-situ* maize stalk mulch + Water hyacinth (5 t/ha)	2.19	1.97	2.64
M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha)	3.54	2.52	3.54
M_4- *In-situ* maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw (2.5 t/ha)	2.46	2.22	2.74
SE (m)±	0.11	0.07	0.11
CD (*P*=0.05)	0.33	0.21	0.34

Table 3: Effect of mulches on harvest index (%) of chickpea, lentil and lathyrus (Pooled mean).

Mulches	Chickpea	Lentil	Lathyrus
M_0- No mulch (residue removal)	26.44	25.20	27.23
M_1- *In-situ* maize stalk mulch (MSM)	27.97	27.72	29.20
M_2- *In-situ* maize stalk mulch + Water hyacinth (5 t/ha)	29.62	28.48	30.29
M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha)	31.52	31.85	32.24
M_4- *In-situ* maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw (2.5 t/ha)	30.89	29.34	31.23
SE (m)±	0.85	1.18	0.86
CD (*P*=0.05)	2.62	3.63	2.63

Table 4: Effect of mulches on yield (kg/ha) of chickpea, lentil and lathyrus (Pooled mean).

Soil moisture conservation measures	Chickpea	Lentil	Lathyrus
M_0- No mulch (residue removal)	710	529	682
M_1- *In-situ* maize stalk mulch (MSM)	931	712	883
M_2- *In-situ* maize stalk mulch + Water hyacinth (5 t/ha)	1179	816	1091
M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha)	1437	975	1526
M_4- *In-situ* maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw (2.5 t/ha)	1264	870	1264
SE (m)±	88	30.54	104.05
CD (*P*=0.05)	271	94	320

Table 5: Effect of mulches on MEY (kg/ha) and system productivity (kg/ha/day) of maize-chickpea, maize-lentil and maize-lathyrus system (Pooled mean).

Cropping systems	MEY	System productivity
CS_1- Maize-Chickpea	2899	34.71
CS_2- Maize-Lentil	1985	32.14
CS_3- Maize-Lathyrus	2167.	30.64
SE(m)±	91	0.41
CD (*P*=0.05)	316	1.43
Mulches		
M_0- No mulch (residue removal)	1522	28.67
M_1- *In-situ* maize stalk mulch (MSM)	2004	30.91
M_2- *In-situ* maize stalk mulch + Water hyacinth (5 t/ha)	2447	32.95
M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha)	3097	35.93
M_4- *In-situ* maize stalk mulch + Water hyacinth (2.5 t/ha) + Paddy straw (2.5 t/ha)	2681	34.02
SE(m)±	106	0.48
CD(*P*=0.05)	306	1.39
Interaction	NS	NS

lathyrus cropping system. Higher MEY in maize-chickpea system was due to short duration (as compared to lentil and lathyrus), higher productivity (lentil) and higher market price of chickpea (Rs 46.2 per kg) and similar results were reported by Walia *et al.* (2011) in maize-based cropping systems.

In case of mulches, significant highest MEY and System productivity was obtained under M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha) as compared to all other mulches. There were 25.44% and 25.32% higher MEY of System and System productivity recorded under M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha) as compared to M_0- No mulch (residue removal) (Table 5). Higher MEY and system productivity under these treatments were due to higher productivity of the crop (Sharma *et al*., 2010).

CONCLUSION

India is the largest producer and consumer of pulses in the world. With the explosive increase of Indian population we will need more pulses to meet the protein demand of the population. Experiments result revealed that mulching with M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha) is the best practice for growing pulses under zero-till condition after maize in maize-legume cropping system. Although there is monetary involvement in mulching M_3- *In-situ* maize stalk mulch + Paddy straw (5 t/ha) still it produces much higher yield than other mulches. Growing of pulses in different cropping system under zero-till condition not only will increase the cropping intensity and production of pulses in the country but also will increase the fertility of the soil.

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