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Effect of tillage on growth and productivity of rainfed maize grown with zero budget natural farming system in Himachal Pradesh

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Abstract

A field experiment was conducted on rainfed maize at CSKHPKV, Palampur during 2018 and 2019 to find out the effect of tillage and irrigation on crop growth parameters and yield. The five treatments viz., a) Zero budget natural farming system (ZBNF) + conventional tillage (CT), b) ZBNF + minimum tillage + mulch (MT+M), c) ZBNF + CT + intercropping (IC), d) ZBNF + MT+M+ IC and e) Organic farming + CT were imposed in a randomized block design with four replications. Results indicated that the ZBNF + MT+M treatment with or without intercropping had higher soil moisture content, emergence count, emergence velocity, relative leaf water content, root parameters, yield and water use efficiency of maize as compared to the treatments with conventional tillage during both the study years.

Key words: Zero budget natural farming system, tillage, seedling emergence, relative leaf water content, root growth parameters, maize yield

Zero Budget Natural Farming (ZBNF) is one such low-input, climate-resilient type of farming that encourages farmers to use low-cost locally sourced inputs, eliminating the use of artificial fertilizers and industrial pesticides. In ZBNF, the soil is supplemented with microbial inoculums like *beejamrit* and *jeevamrit* to accelerate the propagation of soil microflora, beneficial to soil enrichment. *Jeevamrit* and *beejamrit* are cheaper eco-friendly organic preparations made by cow products namely dung, urine, milk, curd and ghee. *Jeevamrit* promotes immense biological activity in the soil and makes the nutrients available to the crop. *Beejamrit* protects the crop from soil-borne and seed-borne pathogens and it improves seed germination also (Sreenivasa *et al*. 2009). Organic manures have a direct effect on plant growth like any other commercial fertilizer. Organic manures also contain traces of micro-nutrients and also provide food for soil microorganisms. This increases the activity of microbes which in turn helps to convert unavailable plant nutrients into available and also fixes atmospheric nitrogen.

Maize, an important crop for food and nutritional security in India, is grown in diverse ecologies and seasons in the country on an area of 9.18 m ha with total production and productivity of 27.23 million tonnes and 2965 kg ha^{-1}respectively. In the past decade (2003-04 to 2012-13), the maize area expanded by 1.8%, production increased by 4.9% and productivity growth at 2.6% per annum witnessed in India which was mainly because of increased maize demand. Maize being shallow-rooted with adventitious root systems has no great influence on the soil physical conditions; on the contrary, it can improve the soil porosity through soil aggregation. Therefore, there may not be a need to till the soil again in the succeeding wheat crop.

In the current scenario, Conservation Agriculture (CA) based crop production technologies are catching the attention of growers and CA-based crop management strategies have been shown to improve crop growth and yield parameters (Jat *et al*. 2014), crop productivity (Das *et al*. 2014; Jat *et al*. 2013) and water-use efficiency (Jat *et al*. 2014: Parihar *et al*. 2016). Himachal Pradesh is a hill state and situated in the lap of Western Himalayas has an abundance of waste materials like wild sage (*Lantana camara*), kali

basuti (*Eupatorium adenophorum*), etc. These materials are growing on the bunds and in pastures nearer to the cultivated land. They have little or no value either as fuel or fodder to the farming community. Hence they can be used as mulch materials for the conservation and carryover of soil moisture without any additional cost, particularly under minimum tillage practice.

Keeping view the above, the present study was conducted to evaluate the effect of conservation tillage on productivity of maize grown with Zero Budget Natural Farming system.

Materials and Methods

The experiment was conducted at the experimental farm, Department of Organic Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur on maize grown under zero budget natural farming system during 2018 and 2019. The experimental site lies in Palam Valley (32^0.6' N latitude and 76^0.3' E longitude) at an elevation of 1290 m above mean sea level of Kangra district of Himachal Pradesh and represents the mid hills sub humid agro climatic zone of Himachal Pradesh in North-western Himalayas. The average annual rainfall of the place is about 2500 mm. The five treatments *viz*., a) Zero budget natural farming system (ZBNF) + conventional tillage (CT), b) ZBNF + minimum tillage + mulch (MT+M), c) ZBNF + CT + intercropping (IC), d) ZBNF + MT+M+ IC and e) Organic farming + CT were imposed in a randomized block design with four replications. An additional treatment of control was also kept as an independent module for general comparison of results. The maize crop variety early composite was sown on June 01, 2018 and June 07, 2019. Preparatory tillage was done with power tiller. Plots with dimensions of 4.00 m length and 2.00 m width providing 8.00 sq.m cultivated area were prepared. After fifteen days, soybean cv. Harit soya was sown as intercrop in respected plots. The harvesting was completed during first fortnight of October 2018 and 2019. The maize crop was grown as a rainfed crop.

In zero budget natural farming system, the seeds were treated with *beejamrit* for 30 minutes before sowing. The FYM @ 250 kg ha^{-1} and *ghanjeevamrit* @ 250 kg ha^{-1} were applied in respective treatments at sowing time. Application of *jeevamrit* @ 500 litres ha^{-1} at 21- 30 days interval during crop growth was given while fermented butter milk @ 12.5 litres ha^{-1} at around 60 days after sowing and at grain filling stage was given. In organic farming treatment, vermicompost @ 10 t ha^{-1} was applied at sowing. In zero budget natural farming system, *jeevamrit* @ 10 per cent was applied as spray at 21-30 days interval, while fermented butter milk was applied at around 60 days after sowing and at grain filling stage. In organic farming treatment, vermiwash @ 5% was applied during the crop growth stages.The conventional tillage was done with power tiller for field preparation and conservation tillage comprised of minimum tillage (opening the soil only for seed and dry manure application) and *lantana* application @ 8-10 t ha^{-1} as mulch.

The changes in soil water content during the season at 0-0.15 and 0.15-0.30 m depths were determined by thermo gravimetric method periodically during crop growth period. Volumetric water content (O) for different depths was calculated by multiplying the water content (w/w basis) with pre-determined bulk density for that depth (Hillel 1998).

The number of seedlings emerged from one meter row length in each plot were counted daily from sowing till they became constant in all the treatments.

The emergence velocity was determined by following formula:

$$\text{Emergence Velocity} = \frac{\text{Emergence}}{\text{Days taken for emergence constant}}$$

The relative leaf water content (RLWC) for both crops was determined after sowing at monthly intervals during 0600 h. RLWC was computed from the fresh weight, turgid weight and oven dry weight according to the method given by Weatherly (1950) as

$$\text{RLWC} = \frac{\text{Fresh weight - Oven dry weight}}{\text{Fully turgid weight - Oven dry weight}} \times 100$$

Root growth parameters, *viz*., root length density and root mass per plant were determined at harvest of crops. Infiltrometer rings (30 cm height) were excavated from randomly selected plants. The cores were kept in water overnight and then roots were

made free from soil by washing with fine jet of water. The roots were collected on fine sieve for final washing with a micro jet tap. Root length was measured in a glass bottom shallow dish of 40 x 20 cm dimensions. Graph paper ruled on mm was placed below the dish. The wet roots were cut from the root shoot joint and spread randomly into the dish containing some water with the help of forceps and needle so that they did not overlap. The long branched roots were cut into smaller pieces. The counts for inter sections of roots (N) with vertical and horizontal lines of 1 cm grid from the graph paper were recorded. Care was taken to avoid more than 400 counts at one instance (Kopke 1979). Root length was computed using the modified version of Newman (1966) formula as proposed by Marsh (1971) and Tenant (1975), as

$$\text{Root length} = \frac{11}{14} \times \text{number of intersections (N)} \times \text{grid uni}$$

Roots were then transferred to a filter paper and pressed gently in its folds to remove imbibed water. The roots then were dried in an oven at 65^0C to a constant weight and finally the dried weight was taken.

The marketable yield was recorded at harvest and expressed in kg ha^{-1}.

The yield obtained for each treatment was divided by the quantity of water used consumptively for the respective treatments for estimating water used efficiency expressed in kg ha^{-1} of water used.

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}\text{)} = \frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Total amount of water used (mm)}}$$

Results and Discussion

Soil moisture content

The soil moisture content at sowing and 51 DAS was higher under the ZBNF+MT+M treatment as compared to treatments with conventional tillage i.e. ZBNF+CT and ZBNF+CT+IC at 0-0.15 m and 0.15-0.30 m soil depths during 2018 and 2019. The treatment with minimum tillage and mulch i.e. ZBNF+MT+M and ZBNF+MT+M+IC were statistically at par with each other. This higher soil moisture content under the treatment with minimum tillage and mulch might be due to the effect of mulch and cover crop that covered the bare ground left between the maize crop and ultimately reduced water loss through evaporation. Similar results were reported by Aboudrare *et al*. (2006) in which they concluded that the little soil disturbance had moisture reserved significantly larger than conventional tillage. There was no significant difference among the treatments with conventional tillage.

Emergence parameters

The emergence count was highest under the ZBNF+MT+M+IC treatment as compared to treatments with conventional tillage i.e. ZBNF+CT and ZBNF+CT+IC during 2018. The treatment with minimum tillage and mulch i.e. ZBNF+MT+M and ZBNF+MT+M+ IC were statistically at par with each other. The organic farming treatment i.e. OF+CT was statistically at par with the treatments grown with conventional tillage (ZBNF+CT and ZBNF+CT+IC). In 2019, the emergence count was significantly higher under the ZBNF+MT+M+IC treatment followed by ZBNF+MT+M treatment as compared to treatments with conventional tillage i.e. ZBNF+CT and ZBNF+CT+IC. Among different treatments with conventional tillage, ZBNF+CT+IC had significantly highest emergence count. The organic farming treatment i.e. OF+CT was statistically at par with the treatments grown with conventional tillage (ZBNF+CT). The highest emergence under the treatments with minimum tillage and mulch might be due to the effect of beneficial microorganisms present in *beejamrit* which resulted in improvement in seed germination and mulch which reduced water loss through evaporation and helped in conserving the soil moisture. Similar results were reported by Sreenivasa *et al*. (2009).

The emergence velocity was highest under the ZBNF+MT+M+IC treatment as compared to treatments with conventional tillage i.e. ZBNF+CT and ZBNF+CT+IC during 2018. The treatment with minimum tillage and mulch i.e. ZBNF+MT+M and ZBNF+MT+M+ IC were statistically at par with each other. The organic farming treatment i.e. OF+CT was statistically at par with the treatments grown with conventional tillage (ZBNF+CT and ZBNF+CT+IC). In 2019, the emergence velocity was significantly higher under the ZBNF+MT+M+IC treatment followed by ZBNF+MT+M treatment as compared to treatments with conventional tillage i.e. ZBNF+CT and ZBNF+CT+IC. Among different treatments with

conventional tillage, ZBNF+CT+IC had significantly highest emergence count. The organic farming treatment i.e. OF+CT was statistically at par with the treatments grown with conventional tillage (ZBNF+CT). This might be due to the better moisture conditions under conservation tillage system that resulted in maximum emergence velocity. Similar results were reported by Sandal *et al*. (2009, 2011) and Sahare and Mahapatra (2015).

Relative leaf water content

The treatment ZBNF+MT+M+IC had highest relative leaf water content (RLWC) at 35 DAS as compared to the treatments with conventional tillage *viz*., ZBNF+CT and ZBNF+CT+IC during 2018. The treatments with minimum tillage and mulch i.e. ZBNF+MT+M and ZBNF+MT+M+IC were statistically at par with each other. Among the treatments with conventional tillage, the treatment ZBNF+CT+IC had significantly higher RLWC. The organic farming treatment (OF+CT) was statistically at par with ZBNF treatments grown with conventional tillage (ZBNF+CT). At 65 DAS, The treatment ZBNF+MT+M+IC had highest relative leaf water content (RLWC) as compared to the treatments with conventional tillage *viz*., ZBNF+CT and ZBNF+CT+IC during 2018. The treatments with minimum tillage and mulch i.e. ZBNF+MT+M and ZBNF+MT+M+IC were statistically at par with each other. The organic farming treatment (OF+CT) was statistically at par with ZBNF treatments grown with conventional tillage (ZBNF+CT and ZBNF+CT+IC). In 2019, the treatment ZBNF+MT+M+IC had highest relative leaf water content (RLWC) at 35 DAS and 65 DAS as compared to the treatments with conventional tillage *viz*., ZBNF+CT and ZBNF+CT+IC. The treatments with minimum tillage and mulch *i.e.* ZBNF+MT+M and ZBNF+MT+M+IC were statistically at par with each other. The organic farming treatment (OF+CT) was statistically at par with ZBNF treatments grown with conventional tillage (ZBNF+CT and ZBNF+CT+IC).

Root parameters

The treatment ZBNF+MT+M+IC had maximum root length density and root mass density as compared to the treatments with conventional tillage *viz*., ZBNF+CT and ZBNF+CT+IC during 2018 and 2019. The treatments with minimum tillage and mulch i.e. ZBNF+MT+M and ZBNF+MT+M+IC were statistically at par with each other. The organic farming treatment (OF+CT) was statistically at par with ZBNF treatments grown with conventional tillage (ZBNF+CT and ZBNF+CT+IC). This might be due to the higher moisture content in mulched and mulched plus intercrop plots that reduced the water loss through evaporation by covering the bare surface. Similar results were reported by the Yang *et al*. (2018) and McMillen (2013).

Yield and water use efficiency

The significant highest yield was recorded in the treatment ZBNF+MT+M+IC as compared to the treatments with conventional tillage viz., ZBNF+CT and ZBNF+CT+IC during 2018. The organic farming treatment (OF+CT) was statistically at par with ZBNF treatment grown with conventional tillage (ZBNF+CT). In 2019, the yield was also significantly higher in the treatment ZBNF+MT+M+IC compared to the treatments with conventional tillage *viz*., ZBNF+CT and ZBNF+CT+IC. Among the treatments with conventional tillage, the treatment ZBNF+CT+IC had significantly higher yield. The highest yield under the treatment with minimum tillage and mulch might be due to the better soil moisture conditions and better root growth which led to better crop growth and increase in yield. Similar results were reported by Parihar *et al*. (2018); Ram *et al*. (2013) and Shao *et al*. (2016).

The WUE was significantly higher under the treatment ZBNF+MT+M+IC as compared to the treatments with conventional tillage *viz*., ZBNF+CT and ZBNF+CT+IC during 2018. The organic farming treatment (OF+CT) was statistically at par with ZBNF treatments grown with conventional tillage (ZBNF+CT and ZBNF + CT + IC). In 2019, the WUE was significantly higher under the treatment ZBNF+MT+M+IC compared to the treatments with conventional tillage *viz*., ZBNF+CT and ZBNF+CT+IC. Among the treatments with conventional tillage, the treatment ZBNF+CT+IC had significantly higher WUE. The highest WUE under the treatments with minimum tillage and mulch might be due to high yield and low total water use. Similar results were reported by Ram *et al*. (2013); Shao *et al*. (2016) and Sharma and Acharya (2000).

Table 1. Effect of tillage on soil moisture content (m^3m^{-3}) and emergence count and emergence velocity during maize 2018 and 2019

Treatments	Soil moisture content (m^3m^{-3})								Emergence count m^{-2}		Emergence velocity (m^2 day^{-1})	
	2018				2019				2018	2019	2018	2019
	At sowing		51 DAS		At sowing		51 DAS					
	0-0.15m	0.15-0.30 m	0-0.15m	0.15-0.30 m	0-0.15m	0.15-0.30 m	0-0.15m	0.15-0.30 m				
ZBNF + CT	0.19	0.25	0.35	0.36	0.18	0.19	0.22	0.23	12.81	10.21	0.99	0.60
ZBNF + MT+M	0.26	0.30	0.40	0.41	0.22	0.24	0.29	0.31	13.52	12.46	1.04	0.73
ZBNF + CT + IC	0.23	0.26	0.35	0.36	0.18	0.19	0.24	0.25	13.06	11.29	1.00	0.66
ZBNF + MT+M+ IC	0.26	0.29	0.39	0.40	0.22	0.23	0.28	0.30	13.83	13.30	1.06	0.78
OF + CT	0.22	0.25	0.35	0.36	0.16	0.19	0.22	0.23	12.67	10.21	0.97	0.60
Control	0.17	0.24	0.33	0.34	0.16	0.19	0.21	0.22	11.54	9.39	0.89	0.55
CD (P=0.05)	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.04	0.40	0.72	0.03	0.04

Table 2. Effect of tillage on relative leaf water content (%)and root growth parameters during maize 2018 and 2019

Treatments	Relative leaf water content (RLWC, %)				Root length density ($\times 10^{-4}$, cm cm^{-3})		Root mass density ($\times 10^{-4}$, g cm^{-3})	
	2018		2019		2018	2019	2018	2019
	35 DAS	65 DAS	35 DAS	65 DAS				
ZBNF + CT	72.46	76.10	71.71	73.42	968.10	959.73	11.75	10.00
ZBNF + MT+M	80.51	80.98	81.01	79.23	975.24	972.70	11.82	11.20
ZBNF + CT + IC	76.56	76.59	72.31	73.48	971.38	969.40	11.77	11.10
ZBNF + MT+M+ IC	81.19	81.14	82.19	80.14	976.26	973.59	11.84	11.24
OF + CT	71.52	75.84	73.72	73.07	966.28	960.28	11.75	10.63
Control	70.59	74.17	73.09	72.20	960.92	956.42	11.69	9.16
CD (P=0.05)	3.46	4.30	4.66	2.94	3.92	2.94	0.03	0.09

Table 3. Effect of tillage and irrigation on biological yield of maize 2018 and 2019

Treatments	2018		2019	
	Grain (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})	Grain (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
ZBNF + CT	2143.75	2.87	1948.85	3.68
ZBNF + MT+M	2293.75	3.49	2218.78	4.20
ZBNF + CT + IC	2817.31	3.76	3062.01	5.89
ZBNF + MT+M+ IC	2990.62	4.03	3932.32	7.42
OF + CT	2143.75	2.90	1944.23	3.70
Control	1825.00	2.41	1673.84	3.14
CD (P=0.05)	166.71	0.22	81.75	0.15

Conclusion

The two years study in maize indicated that the treatment of minimum tillage with mulch with or without intercropping of soybean resulted in higher soil and relative leaf water content, higher seedling emergence, improved root growth and higher crop and water productivity in comparison to the conventional tillage and no mulch under rainfed conditions.

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