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Agronomic responses of maize to deficit and adequate irrigation and levels of chemical fertilizers and bio fertilizers

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ABSTRACT

In 2014, over 180 thousand hectares and 1.223 million tons of Maize produced in Iran. However Iran is a major importer of Maize in the world. Kermanshah is located in Western Iran and Maize is the most important crop after wheat. Maize production in this province has two major problems: water shortage caused and low percentage of organic matter in soil. In this research, effects of vermicompost and Azotobacter as a boi- fertilizers and chemical fertilizers on yield and yield components of Maize under normal and deficit irrigation was investigated in two sites in 2014 and 2015. Site included normal irrigation and deficient irrigation (65% optimum water requirement) and each site was conducted as the factorial split plot in a randomized complete block design with three replications. Treatments included Azotobacter in the main plots (non-inoculation and inoculation), vermicompost (consuming 0, 2, 4 and 6 ton/ha) and chemical fertilizers included N,P,K in tree levels (100% recommendation based on soil test, 50% recommendation and no fertilizer) in the sub plots. Results showed that grain yield, 1000 kernels weight, number of kernels per row, number of kernels per ear and plant height were decreased by deficient irrigation. Use of Azotobacter and vermicompost significantly increased these traits in normal and deficit irrigation, Results also showed that using 6 ton/ha of vermicompost and *Azotobacter* in soil, 50% of the corn fertilizer supplied. The results showed that combined use of bio-fertilizers with chemical fertilizers increased the yield and yield component. Therefore the uses of biological fertilizers significantly reduce the consumption of chemical fertilizers and reduce the adverse environmental effects. So biofertilizers could be considered as a suitable substitute for chemical nitrogen fertilizer in organic agricultural systems. On the other hand from this experiment, application of vermicompost in combination with chemical fertilizers showed better performance than only chemical fertilizers, even in 100% recommendation based on soil test treatments.

KEY WORDS: MAIZE, VERMICOMPOST, AZOTOBACTER, CHEMICAL FERTILIZER, INM, YIELD

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INTRODUCTION

Maize (*Zea mays* L.) is an important crop that used as food, feed and industrial products. Maize is the third most important cereal after wheat and rice all over the world and the world's largest grain crop in term of total production on a MT basis. Maize is currently produced on nearly 184 million hectares in 125 developing countries and is among the three most widely grown crops in 75 of those countries (FAOSTAT, 2015).

Kermanshah is located in western Iran and Maize is the most important crop after wheat, grown on an area of 45,000 ha with the production of 382,500 tones with 8500 kg ha-1 average grain yield; the third and first place of Iran for area harvested and mean yield, respectively. Maize production in this province has two major problems: water shortage caused by drought in recent years and low percentage of organic matter in soil, which in most areas is less than one percent. Maize is an irrigated crop in Iran and recent drought periods in Iran imposed pressure on groundwater resources. The groundwater is the primary source of irrigation of Maize production in province and in recent years, the water storage has gradually decreased in this region mainly because of increasing annual irrigation and the dry climate (Agricultural Department of Kermanshah, 2015).

Drought is the most common abiotic environmental stress limited the production at approximately 25 % of the world agricultural land. Yield losses include more than two- thirds of the total damage of abiotic stresses due to drought, salinity and other factors. Maize, however, is highly sensitive to drought, specifically two weeks prior and post-silking (Tollenaar and Lee, 2011). Among the abiotic stresses, drought is the most severe limitation to Maize production. Water stress adversely affects crop growth and yield in many regions of the world. One of the most important constraints for agriculture is water limitation. Most recently, global warming may be worsening this situation in most agricultural region (Jabasingh and Babu, 2014).

The drought stress decreases the Maize yield due to three main mechanisms: 1- by reducing the amount of photosynthetic active radiation received by vegetation canopy (due to decreasing growth of leaves and leaf premature senescence), 2- by reducing efficiency of energy and 3- by reducing the harvest index (due to less allocation of assimilates to crop economic yield) (Hlavinka and et al., 2009). Adequate water and nutrient supply are important factors affecting optimal plant growth and successful crop production. Water stress is one of the severe limitations of crop growth especially in arid and semiarid regions of the world as it has a vital role in plant growth and development at all growth stages (Taleshi and Osoli, 2015)

The addition of organic matter to the soil usually increases the water holding capacity of the soil. This is because the addition of organic matter increases the number of micropores and macropores in the soil either by "gluing" soil particles together or by creating favourable living conditions for soil organisms. Certain types of soil organic matter can hold up to 20 times their weight in water. The consequence of increased water infiltration combined with a higher organic matter content is increased soil storage of water (Reicosky, 2005).

Hudson (1994) showed that for each 1-percent increase in soil organic matter, the available water holding capacity in the soil increased by 3.7 percent. Soil water is held by adhesive and cohesive forces within the soil and an increase in pore space will lead to an increase in water holding capacity of the soil. As a consequence, less irrigation water is needed to irrigate the same crop. The use of biofertilizer in condition of environmental stress can decrease effects of stress and enhance soil water holding capacity, root growth and yield (Li and Ni, 1996). By increasing soil organic matter content, composts improve soil physical properties such as structural stability, total porosity and hydraulic conductivity, aggregate formation and water holding capacity. However, the effect of composts on plant available water varies, depending on soil type, the type of compost and application rate (Nguyen et al., 2012).

Compost produced from organic dairy cattle manure can result in higher soil water content under Kentucky bluegrass (*Poa pratensis* L.) after 8 days without addition of water (Johnson et al. 2009). Also Gholipoor et al. (2014) reported that vermicompost can alleviate the deleterious effects of drought stress on grain yield of chickpea. Moreover, the use of organic matter such as animal manures, compost and vermicompost has long been recognized in agriculture as beneficial for plant growth and yield and the maintenance of soil fertility. The new approaches to the use of organic amendments in farming have proven to be effective means of improving soil structure, enhancing soil fertility and increasing crop yields. Organic matter is excellent source of plant-available nutrients and their addition to soil could maintain high microbial populations and activities. In recent years vermicompost an organic amendment has been selectively and effectively used in soil conditioning and in varying degrees to influence the soil properties. Among various sources of organic matter, vermicomposts have been recognized as having considerable potential as soil amendments. Vermicomposts are products of organic matter degradation through interactions between earthworms and microorganisms. The process accelerates the rates of decomposition of the organic matter, alters the physical and chemical properties of the material, and lowers the C:N ratio, leading to a rapid humification process in which the unstable organic matter is fully oxidized and stabilized (Arancon et al., 2005).

The cost of inorganic fertilizers is very high and sometimes it is not available in the market for which the farmers fail to apply the inorganic fertilizers to the crop field in optimum time. On the other hand, the organic manure is easily available to the farmers and its cost is low compared to that of inorganic fertilizers. One of the main practices in sustainable agriculture is application of biologic and organic fertilizers in order to provide plants nutrients and to reduce the need for chemical fertilizers. Vermicompost is an important type of non chemical fertilizers. Bio-fertilizer is a densely populated preservative of one or more types of useful terricolous microorganism, their metabolic phenomenon are used to provide the nutrients needed by plants, control soil-borne diseases and maintain the stability of soil structure (Vessey, 2003). Furthermore, compost has a high nutritional value, with high concentrations of especially nitrogen, phosphorus and potassium, while the contamination by heavy metals and other toxic substances are very low, and also positive changes have been reported in the quality of wheat flour, because of increasing the amount of gluten after compost treatment (Gopinath, 2008).

Many attempts have been tried to replace a part of those harmful fertilizers by biofertilizer. Integrated nutrient management strategies involving chemical fertilizer and biofertilizer have suggested enhancing the sustainability of crop production (Esmailpour et al., 2013). Previous studies showed that the combination of compost with chemical fertilizer further enhanced the biomass and grain yield of crops (Sarwar et al., 2008). Also the synergistic effect of combining farm and mineral fertilizers application has been confirmed. Kmetova and Kovacik (2014) reported where the joint application of vermicompost and nitrogen fertilizer increased the rice crop of 15.6 % compared to the only application of nitrogen fertilizer.

On the other hand, El-Afry et al (2012) reported that application of *Azotobacter* in Wheat, act as protective factors against irrigation water deficit and could overcome the negative effects of drought stress. The use of rhizosphere associated microorganisms as biofertilizers is now being considered as having potential for improving plant productivity (Vessey, 2003). Biofertilizers are able to fix atmospheric nitrogen in the available form for plants. Rhizosphere-associated nitrogen fixing and phosphate-solubilizing bacteria have been used as inoculum for nonlegume crop species such as Maize, rice, wheat, and sugarcane (Mehnaz and Lazarovits, 2006). Many attempts have been tried to replace a part of those harmful fertilizers by biofertilizers in Maize to get yield of a good quality without loss in its quantity (Kholy et al., 2005). Inoculation of Maize and wheat seeds with Azotobacter and *Azospirillum* increased plant growth, nutrients uptake and yield (Dobbelaere, et al., 2001). El-kholy and Gomma have succeeded to reduce the recommended dose of chemical fertilizers in Maize and millet by 50%, using biofertilizers without significant yield loss. A pot experiment was conducted by Mudenoor et al., (2007), to study the effects of seed treatment of micro nutrient supplemented *Azospirillum* biofertilizer on dry mater production and yield of Maize at Karnataka and result indicated high shoot and root dry matter with seed treatment of *Azospirillum*. *Azospirillum* spp. are commonly isolated bacteria from the rhizosphere of various grasses and cereals and are well characterized as plant-growth-promoting rhizobacteria (PGPR). Many published reports exist on the use of Azospirillum spp. for inoculation of cereals (Mehnaz and Lazarovits, 2006). In France, *Azospirillum lipoferum* is used as commercial fertilizer for Maize under the trade name AzoGreen-m (Jacoud et al, .1999). Integrated plant nutrient management (INM) is the combined use of mineral fertilizers with organic resources such as cattle manures, crop residues, urban/rural wastes, composts, green manures and biofertilizers (Kemal and Abera, 2015).

Various studies revealed that sustainable yield and yield related parameters of maize are significantly improved by integrated nutrient management (INM) practices. INM including vermicompost showed best results in yield parameters of maize like number of grains per cob, weight of the cob, 100 seed weight and yield (Kannan et al., 2013). Also Kemal and Abera (2015) reported application of recommended dose of inorganic fertilizer along with vermicompost at 6 ton/ha to maize not only enhanced productivity of maize but also improved soil fertility in terms of higher available N, P, K and organic carbon content over the control and recommended N, P and K, moreover.The objective of this study was to determine the effect of biofertilizers and chemical fertilizers on yield and yield components of Maize under normal and deficit irrigation condition in western Iran region and looking for the best biological treatments could be applied to the maize to get a high yield in addition to keep our environment clean and safe.

MATERIAL AND METHODS

Characterization of the experimental area

Field experiments were conducted for two years (2014–2015) at the agricultural research farm, Agricultural and Natural Resources Research Centre in Kermanshah, Iran. This farm is located at 34.08 N, 46.26 E, 1345 m altitude, silty clay soil, pH=7.5-8, 450 mm precipitation Mediterranean climate. Table 1 gives the properties of the experimental field.

Table 1. Soil characteristics

Zn ppm	Fe ppm	Mn Ppm	O.C%	N%	av.K Ppm	av.P ppm	Depth Cm
0.58	5.9	7.2	0.8	0.08	640	11.6	0-30
0.52	3.8	6.4	0.9	0.1	640	7.8	30-60

Application of the treatments

In this research, effects of vermicompost and Azotobacter as a boi- fertilizers and chemical fertilizers on yield and yield components of Maize under normal and deficit irrigation was investigated in two sites. Sites included normal irrigation and deficient irrigation (65% optimum water requirement) and each site was conducted as the factorial split plot in a randomized complete block design with three replications and three factors. Treatments included Azotobacter in the main plots (non-inoculation and inoculation), vermicompost (consuming 0, 2, 4 and 6 ton/ha) and chemical fertilizers included N,P,K in tree levels (100% recommendation based on soil test, 50% recommendation and no fertilizer) in the sub plots. The Maize cultivar used was “KSC 704” (a grain Maize cultivar that is commonly planted in the region). Entire experimental area was chisel-plowed in the fall and plowed in the spring before planting. Soil samples were taken before the imposition of treatments and were analyzed for physical and chemical characteristics.

Experiment plots were seeded with 75 cm row to row distance and plant density was 75000 plant/ha (conventional plant density). Maize was planted in May 2014 and 2015 and by experimental planter. Seeds were sown 5 cm deep. Before planting 7g inoculation with 1g had 107 active and live bacteria, were used inoculating seeds. Seeds which must mix with Azotobacter soaked with sugar water with concentration 2% and with ratio 2kg inoculation 100kg seeds. Plot dimensions using in this study will be 7m long by 3m wide, each plot will be consisted four rows spacing at 0.75m. Vermicompost used in this study has been produced by the activity of *Eisenia foetida* worm produced from cattle manure. The amount of acidity and electrical conductivity of its aqueous solution are 7.5 and 14.65 dS/m, respectively. Phosphorus and potassium fertilizers were mixed by soil before cultivation. A quarter of urea fertilizer at planting, one-fourth of 6 to 8 leaf stage, and the remaining fertilizer was applied prior to flowering, before planting all quantities of vermicompost was mixed with soil to a depth of 30 cm. Weeds were removed manually across the growing season.

Irrigation

Maize is an irrigated crop in Iran; therefore, it is not dependent on the seasonal rainfall. Irrigations were carried out at 7 day intervals. Water treatments (deficit and adequate irrigation) were initiated during middle vegetative growth stage (around V6). Beginning on these dates, water was applied at weekly intervals based on the amount of evapotranspiration for the previous week as determined by the on-site weather station using a modified version of the Penman FAO equation (O'Neill et al., 2004). The adequate irrigation treatment received the amount of water required to fully replace the previous week evapotranspiration while the deficit treatment received 65 % this amount. This was continued throughout the remainder of the growing season. Water entrance to plots was measured by counter and Hydrofix irrigation system

Variables

Each plot was harvested at maturity for yield and yield components. The Maize ears located 6 m2 from each plot were harvested by hand, then allowed drying at 80°C to a constant weight and then seed yield was obtained. Before final harvesting Maize yield components including the number of ears per plant and the number of seeds per ear were determined on five randomly selected plants in the center rows of each plot. 100-seed weight was measured according to the recommendation of the International Seed Testing Association (ISTA).

RESULTS AND DISCUSSION

Grain yield

The yield of maize was significantly influenced by deficient irrigation (Table 2); Results showed that during the both research years, grain yield was decreased from 8.2 ton/ha to 4.4 ton/ha by deficient irrigation. Water deficit in maize is one of limiting factors of yield and at the time of pollination, drought may have severe impact on yield (Moser et al., 2006). These results are consistent with previous work; Dagdelen et al. (2006) reported that water deficiency significantly affected maize yield and the highest maize yield was obtained from the full irrigation treatments. Stone et al. (2001) reported that water deficit reduces crop growth and morphological characteristics of maize plant. Pandey et al. (2000) reported that yield reduction (22.6 - 26.4%) was found with deficit irrigation and this was associated with decrease in kernel number and weight. Also Karam et al. (2003) stated that water deficiency significantly reduced dry matter accumulation and as a result grain yield deceased in maize.

Table 2. AOVA table of fresh and dry yield of data 2014 and 2015 (in brief).

S O V	df	MS				
		Yield	kernel weight	Number of kernels per row	Number of kernels per ear	Plant height
Replication	2	ns	ns	ns	ns	ns
Year	1	ns	ns	ns	ns	ns
Year* replication	2	ns	ns	ns	ns	ns
Irrigation	1	**	**	*	**	**
Error	8	-	-	-	-	-
Azotobacter	1	ns	ns	ns	Ns	ns
Azotobacter * Irrigation	1	ns	ns	ns	Ns	ns
Year*Vermicompost * Irrigation	1	**	**	**	**	**
Error	8	-	-	-	-	-
N P K	2	**	**	*	**	**
Azotobacter * N P K	2	ns	ns	ns	Ns	ns
Irrigation* N P K	2	**	**	**	**	**
Azotobacter *Irrigation* N P K	2	**	**	*	**	**
Vermicompost	3	**	**	*	**	**
Vermicompost *Irrigation	3	**	**	**	**	**
N P K*Vermicompost *Irrigation	6	**	**	**	**	**
N P K*Vermicompost *Irrigation* Azotobacter	6	**	**	**	**	**
Year* N P K*Vermicompost *Irrigation* Azotobacter	24	**	**	**	**	**
C.V.		8.8	9.6	8.9	10.5	11.1

ns: not- significant; * significant at 5-% ($P<0.05$), ** significant at 1-% ($P<0.01$)

Analysis of variance showed that Azotobacter increased grain yield about 89 kg/ha in all treatments (Table 4). In addition the use of vermicompost at 2, 4 and 6 ton/ha consistently and significantly increased grain yield in normal and deficit irrigation (Table 4). Although, application of vermicompost led to increase in grain yield, the highest grain yield was related to integrated treatments 6 ton/h vermicompost and 100% chemical fertilizers recommendation based on soil test. Results also indicated that the use of 6 ton/ha vermicompost and Azotobacter in soil, 50% of the maize fertilizer supplied. The results showed that combined use of bio-fertilizers with chemical fertilizers increased the grain yield. Therefore the uses of biological fertilizers significantly reduce the consumption of chemical fertilizers and reduce the adverse environmental effects.

On the other hand from this experiment, application of vermicompost in combination with chemical fertilizers showed better performance than only chemical fertilizers, even in 100% recommendation based on soil test treatments. It can be stated that the increase in growth parameters of maize are due to greater availability of nitrogen in full organic and integrated treatments. In full chemical treatments most of nitrogen would be leached from the soil profile. In addition, high porosity and water holding capacity of vermicompost that helps

Table 3. Effects of chemical fertilizer and vermicompost on yield

	Chemical Fertilizers included N P K											
	No Fertilizer				50% Recommendation				100% Recommendation			
Irrigation \ Vermicompost (ton/ha)	*0*	*2*	*4*	*6*	*0*	*2*	*4*	*6*	*0*	*2*	*4*	*6*
Normal 100%	4.4	5.3	5.9	7	7.3	8	8.5	10.3	10.2	10.3	10.3	10.7
Deficient 65%	2.8	3.1	3.8	4.2	4.1	4.7	4.8	5.3	4.7	5.3	5.4	5.5

Table 4. Effects of *Azotobacter* and vermicompost on yield

	Azotobacter							
	Non-inoculation				Inoculation			
Vermicompost (ton/ha) / Irrigation	0	2	4	6	0	2	4	6
Normal 100%	3.8	4.3	4.6	4.9	3.9	4.4	4.7	5.1
Deficient 65%	7.3	7.8	8.2	9.3	7.3	7.9	8.2	9.5

Table 5. Effects of Chemical and bio fertilizer on yield

		Deficient Irrigation				Normal Irrigation			
Azotobacter	Vermicompost (t/ha) / NPK Recommendation	0	2	4	6	0	2	4	6
non-inoculation	No Fertilizer	2.6	3	3.7	4.1	4.3	5.1	5.7	6.8
Inoculation	No Fertilizer	2.8	3.1	3.9	4.4	4.4	5.4	5.9	7
non-inoculation	50%	3.9	4.6	4.7	5.1	7.2	7.9	8.4	10
Inoculation	50%	4.3	4.8	4.9	5.3	7.4	8.1	8.5	10.4
non-inoculation	100%	4.8	5.2	5.2	5.4	10	10.2	10.2	10.5
Inoculation	100%	4.7	5.3	5.4	5.5	10.2	10.3	10.3	10.6

in better aeration and drainage. Moreover use of 6 ton/ha vermicompost and Azotobacter in treatments with no chemical fertilizers produced 7 and 4.4 ton/ha grain yield in normal and deficit irrigation respectively. Application of organic manures either alone or integrated with chemical amendments for maize, performed better than all amendments tested in laboratory trails studied by Mujeeb et al. (2010). Recommendation of organic matter alone with synthetic fertilizers could be helpful for enhancing stagnant wheat grain yield was reported by Tahir et al. (2011). Similarly Fanuel and Gifole (2012) recommended applying combination of compost at 5 ton ha-1 along with inorganic fertilizer to obtain better yield of maize.

Naganand a et al., (2010) in their experiments observed that inoculation of maize with Azotobacter and Azos-

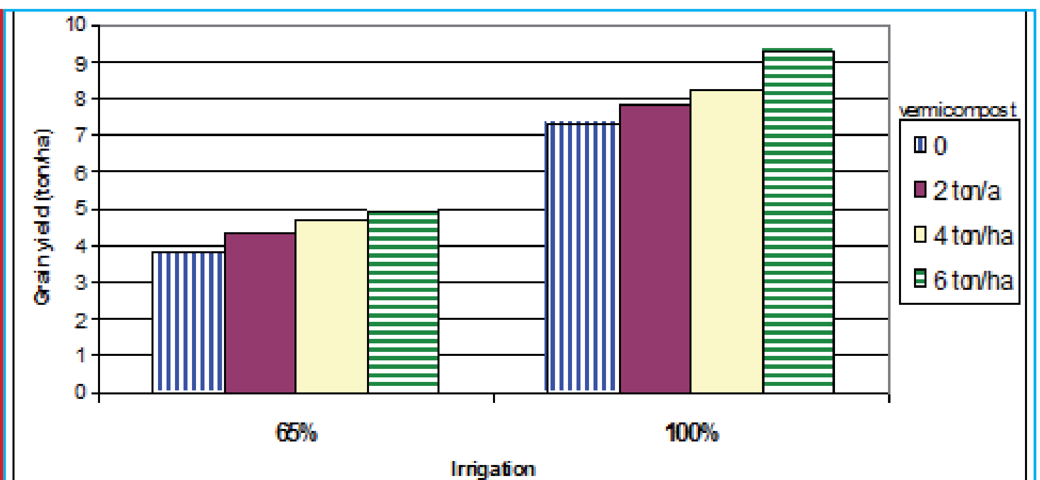

FIGURE 1. Effect of vermicompost and imigation on grain yield

Table 6. Effects of chemical fertilizer and vermicompost on 1000 kernel weight

Vermicompost (ton/ha) / Chemical Fertilizers	Deficient Irrigation				Normal Irrigation			
	0	2	4	6	0	2	4	6
No Fertilizer	213.6	235.2	240	263	260.3	269.7	281.1	316
50% Recommendation	240.5	259.3	271.7	283	288.5	304.2	319.8	326.9
100% Recommendation	274.8	278.6	279.8	284.6	327.6	330.7	331.4	337.3

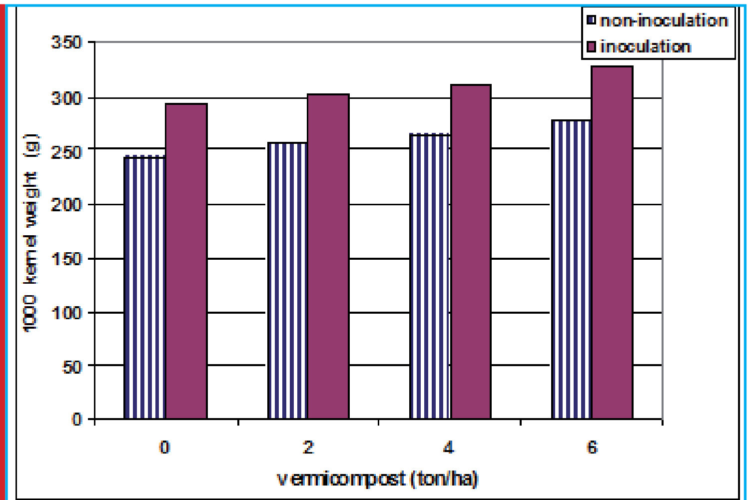

FIGURE 2. Effect of vemicompost and azotobacter on kernel weight

pirillum bacteria, leads to yield increasing in sections of nitrogen fertilizer.

1000 kernel weight

The results of this study showed that vermicompost and chemical fertilizers had a significant effect on 1000 kernel weight during both the years (Table 6). Vermicompost and Azotobacter increased 1000 kernel weight and also chemical fertilizers. The heaviest 1000 kernel weight 331.8 g was recorded in the plots where 6 ton/ha vermicompost and 100% chemical fertilizer were applied but with use of 6 ton/ha vermicompost and 50% chemical fertilizer 1000 kernel weight was 327.3 g and no significant different was observed. Also without chemical fertilizer and with use of 6 ton/ha vermicompost and Azotobacter, 1000 kernel weight was 315.7 g and 263g in normal and Deficient Irrigation condition respectively.

Ramasamy et al. (2011) reported vermicompost increased kernel weight in maize. Similarly, Cheema, et al. (2010) found that applying 50% N from poultry manure and remaining from urea fertilizer produced maximum grain yield of maize and grain weight per cob. Kalhapure and et al. stated that (2013) Azotobacter and compost increased 1000-grain weight in maize. Similar results were described by Yazdani et al. (2009) that grain weight of maize increased with the application of phosphate solubilizing microorganisms.

Table 7. Effects of chemical fertilizer and vermicompost on number of kernels per row

Vermicompost (ton/ha) / Chemical Fertilizers	Deficient Irrigation				Normal Irrigation			
	0	2	4	6	0	2	4	6
No Fertilizer	33.4	33.2	35.5	36	39.1	39.3	45	45,6
50% Recommendation	36.5	36.3	38.3	38.7	46.8	47	48.4	48.6
100% Recommendation	39	39.3	40	40.5	48.3	48.3	49	49

Table 8. Effects of Azotobacter and vermicompost on number of kernels per row

	Azotobacter							
	Non-inoculation				Inoculation			
Irrigation \ Vermicompost (ton/ha)	0	2	4	6	0	2	4	6
Normal 100%	41	42	47	47.2	47.6	47.8	48	48.1
Deficient 65%	34.7	35	36.5	36.7	37.6	37.6	39.3	39.5

Table 9. Effects of chemical fertilizer and vermicompost on number of kernels per ear

	Deficient Irrigation				Normal Irrigation			
Chemical Fertilizers \ Vermicompost (ton/ha)	0	2	4	6	0	2	4	6
No Fertilizer	405	461.8	471.5	512.7	464.1	659	662.6	674.2
50% Recommendation	495.6	523.3	545.8	581.4	680.4	729.4	749.9	751.1
100% Recommendation	551.6	556.4	568.5	594.9	718.6	735.3	757.1	763.2

Whereas results of this experiment showed that drought stress reduced 1000 kernel weight from 307.8 g to 260.3 g. In deficient irrigation condition by increase vermicompost and chemical fertilizer kernel weight was increased. Nevertheless, uses of vermicompost and Azotobacter in this condition were increased kernel weight. Karam et al. (2003) stated that water deficiency significantly reduced dry matter accumulation. Grain yield reduced to 37% due to a decline of 18% in kernel weight and of 10% in kernel number under water stress conditions. Increase in 1000-grain weight of common millet due to the application of humic acid was informed by (Veysel et al., 2011). Beigzade et al. (2013) reported bacteria (Azospirillum + Pseudomonas) increased grain weight in maize.

Number of kernels per row

Number of kernels per row was affected by water shortages. Number of kernels per row in normal and deficient irrigation was 46.2 and 37.1 respectively. In addition Analysis of variance of the data showed the main effects of chemical fertilizers and biofertilizers and interaction of chemical and biofertilizers were significant. Similarly with other traits in deficient irrigation condition by increase vermicompost and chemical fertilizer kernel weight was increased. The maximum number of kernels per row 49 was observed in 100% chemical fertilizer, but Number of kernels per row in treatment with 50% chemical fertilizer and 6 ton/ha vermicompost and use of Azotobacter was 48.5. Results showed that using 6 tons of vermicompost and Azotobacter, reduced use of chemical fertilizers by 50%. Whereas this trait in condition with use of 6 ton/ha vermicompost and Azotobacter without chemical fertilizer was 45.6. Moreover Azotobacter increased number of kernels per row from 40.2 to 43.2 (Table 7 and 8)

INM including vermicompost showed best results in yield parameters of maize like number of grains per cob, weight of the cob, 100 seed weight and yield (Kannan et al., 2013). Beigzade et al. (2013) showed that phospho-

Table 10. Effects of Azotobacter and vermicompost on number of kernels per ear

	Azotobacter							
	Non-inoculation				Inoculation			
Irrigation \ Vermicompost (ton/ha)	0	2	4	6	0	2	4	6
Normal 100%	618.7	707.5	714.6	724.1	623.6	721.7	731.8	734.9
Deficient 65%	480.7	509.1	521.3	554.7	490.8	526.5	526.5	571.3

Table 11. Effects of chemical fertilizer and vermicompost on plant height

	Deficient Irrigation				Normal Irrigation			
Vermicompost (ton/ha) / Chemical Fertilizers	0	2	4	6	0	2	4	6
No Fertilizer	147.1	164.6	168	171	201.9	208.9	213.8	219.3
50% Recommendation	158.2	167.3	168.5	174.5	216.5	220.6	229.1	235.5
100% Recommendation	162.1	175.2	175.1	177.5	230.7	231	236	237.4

Table 12. Effects of Azotobacter and vermicompost on plant height

	Azotobacter							
	Non-inoculation				Inoculation			
Vermicompost (ton/ha) / Irrigation	0	2	4	6	0	2	4	6
Normal 100%	154.9	166.7	170.5	171.5	156.8	171.4	172.6	174.2
Deficient 65%	214.7	221.2	227.8	232.3	218	219.1	224.8	229.1

rus fertilizer and bacteria (Azospirillum + Pseudomonas) growth had a significant effect on number of grains per row, but interaction effect of these two factors had not significant effect on mentioned trait. Baral and Adhikari (2013) reported that the numbers of kernels per row was significantly influenced by Azotobacter

Number of kernels per ear

Results showed that deficient irrigation decreased number of kernels per ear and the other hand vermicompost, Azotobacter and chemical fertilizers had a significant effect on number of kernels per ear (Table 3). Maximum number of kernels per ear was recorded to inoculation with Azotobacter, 6 ton/ ha vermicompost and 100% chemical fertilizer (763.2) and with use of Azotobacter, 6 ton/ ha vermicompost and 50% chemical fertilizer this treat was 749.4. So, biofertilizers was decreased chemical fertilizer 50% (Table 9 and 10).

Grain yield of maize is product of three yield components i.e. the number of ears per unit of area, the number of grains per ear and the unit grain weight (Gardner et al., 1985). Variation in any one of these components, keeping the size of other components constant, contributes to increase or decrease in grain yield, and thus any management factor which increase any of these components, will increase the final grain yield.

3.5 Plant height

Inoculation with Azotobacter and use of vermicompost significantly influenced the plant height. Two years mean revealed that maximum plant height (236.5) was recorded with the application of recommended dose of chemical fertilizer plus 6 ton/ha vermicompost and Azotobacter inoculation and in normal irrigation. Minimum plant height (147.1) was observed in deficient Irrigation and without chemical and bio fertilizer. In both irrigation treatments with increasing of chemical and bio fertilizer plant height was increased (Table 11 and 12). Baral and Adhikari (2013) reported Azotobacter increased plant height in maize. Alnoaim and Hamad (2004), reported that by using of bio-fertilizers with using of N fertilizer the highest plant height, number of tiller and grain yield of rice (Oryza sativa) were achieved. Maize plant height increased application with 10 t/ha farm yard manure (Karki, et al., 2005).

CONCLUSION

Although the vermicompost and Azotobacter were not able to provide all the nutritional requirements for Maize but the results indicated that the use of 6 ton/ ha vermicompost and Azotobacter in soil, 50% of the maize fertilizer supplied and that means a 50% reduction in the consumption of chemical fertilizers and less pollution of the soil and the environment. On the other hand, the results showed that under deficient irrigation vermicompost and Azotobacter increased grain yield. As a general conclusion these results suggested that integrating organic sources with 50% of recommended NPK fertilizers are appropriate for sustainable crop production in normal and deficient irrigation.

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