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Research Article

Integrated Soil Management Effects on Physiological Response, Water Use Efficiency and Productivity of the Maize Crop

[1,2]Bakht Munir, [1]Pitipong Thobunluep, [1]Ed Sarobol and [3]Nantawan Sarobol

[1]Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand
[2]Department of Agronomy, Faculty of Agriculture, Nangarhar University, Afghanistan
[3]Field and Renewable Energy Crops Research Institute, Department of Agriculture, Royal Thai Government, Thailand

Abstract

Background and Objective: Food scarcity is one of the numerous challenges, encountered by the globe. Improvement in food production is highly demanded to overcome this issue. To increase maize production, soil fertility and productivity is required to be enhanced. The current study was designed to use integrated organic and inorganic fertilizers and polymers to improve soil conditions and increase the production of maize crop under the control conditions. **Materials and Methods:** Nine different treatments, i.e., T_1 (Soil+Nitrogen), T_2 (Soil+Potassium), T_3 (Soil+Phosphorus), T_4 (Soil+NPK), T_5 (Soil+Compost), T_6 (Soil+Polymer), T_7 (Soil+(NPK+Compost), T_8 (Soil+(NPK+Polymer) and T_9 (control soil) were studied. **Results:** Results depicted that the highest production of maize crop in terms of harvest index (HI, 0.68%) and seed weight (109.64 g per cob) was found in T_8 than all the other treatments. Similarly the physiological parameters such as Plant height, LAI, CGR, NAR were found significantly higher in T_8 at all growth stages (20, 40, 60 and 90 DAS). Additionally, the crop water use efficiency was also improved by T_8 treatment (22.7 kg h^{-1} mm^{-1}). **Conclusion:** The study indicated that implementation of super absorbed polymer mixed with NPK fertilizer could play a better role to improve the soil condition and increase the productivity of maize. This may be due to its better of water holding capacity for longer period of time which could be beneficial for drought affected areas.

Key words: Crop physiology, crop production, integrated nutrient management, soil fertility, polymer

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Corresponding Author: Pitipong Thobunluep, Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand
Tel: +66 870093646

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Maize one of the most cultivated crop worldwide belongs to family Poaceae[1, 2]. Maize as a human food using in different forms, it contain approximately 88% carbohydrates, 16% proteins, 5.7% fats and 1.3% minerals and has high nutritional value using worldwide[3-5]. Production of the maize estimated to be around 70 million t[6]. It is in number third after wheat and rice, but in forth on commercial ranking[7]. Maize cultivation area increasing every year, but the production is still low especially in developing countries. Globally cultivated land of maize which is nearly 67% but their production is only about 46%, where approximately 60% of the world maize is produced by USA and China collectively[8].

World's population is expected to be reached around 9.8 billion by 2050. Whereas increasing rate of the population needs to more foods around 70% to feed the population up to next by 2050. Therefore global food production must increase[9] by 70% by 2050. However around17% of the world arable land irrigated and produced 40% of the word food[10]. The major causes of low maize yield by low soil fertility and insufficient uses of chemical fertilizers resulting sever food scarcity[7], to recover the soil nutrient depletion, the application of the inorganic fertilizers is essential[11]. Uses of combine organic and inorganic fertilizers in terms (INM), integrated nutrients management which good for high yield and soil health. The integrated application is not only to replenish the plants requirements to produced high yield and profitability of the field crops but also has synergetic effects to maintain the permanent fertility status of the soil.

The NPK fertilizers are the essential fertilizers elements, consequently for higher yield; it can lead rapidly the crop yield. Despite could be profound effect on soil physical, chemical and biological properties, whereas sole using chemical fertilizers caused of toxicity, burning, soil compaction, soil pollutions, which are also consider the limiting elements. Maize needs to adequate amount of nutrients particularly nitrogen, phosphorus and potassium for good growth and high yield. These elements depleting time by time in soil, one of the way to address the impact deficiency in the soil through the use of combine organic and inorganic fertilizers[12]. Frequently uses of N-fertilizer reduced the losses of N-fertilizers while increased the maize quality and quantity[13]. Nitrogen content in plants ranges between 1-6 g in 100 g of dry tissues. Under nitrogen deficiency plants grow slowly, weak and stunted[14]. Phosphorus is one of the important elements placed in soil[15] from 0.001-1 mg L^{-1}, Necessary for good growth and high production[16,17].

Potassium regulates the osmotic potential of the cells, responsible for closing and opening the stomata. It plays a vital role in water plant relationship; it is involved to uptake water from the soil. The proper amount potassium improves plant resistance to stress, lodging, drought, pest and disease[18]. Low resistance to disease, weak stalk and lodging, scorching or burnt along leaves tips and margins are the common symptoms of potassium deficiency[19-20]. Potassium exist in the soil solution in the form of K^+ cation and root can absorbed it in an ionic form which might lost by leaching. One way to reduce the leaching of the K^+ from soil is to add the organic materials. Organic materials usually has large CEC (cation exchange capacity), which can replenish K^+ effectively[19,20]. Organic manure includes FYM farm yield manure, animal manure, plants residuals, compost and bio- fertilizers, which improved the soil productivity[21].

Using the organic matter increases phosphorus and all plant nutrients availability finally high yield, similar to inorganic fertilization[22-23]. It is observed that nutrients use efficiency increased with combine used of organic manure[24] 10 t ha^{-1}. It is concluded that neither organic manure nor inorganic fertilizers alone can result in sustainable productivity[25].

Polymer or SAP (super absorbent polymer), hydrophilic contains carboxylic groups (-CooH)[26]. It is imbibe the water more than 400 times to their weight and release 95% retained water to plants used to make plants resistant in water stress conditions[27]. Uses polymers 0.5% w/w increase numbers of days to wilting point from 12-13 in barley cropping system compare to non-polymers plots treated by drought, which also improved soil properties and microbial activities[28-29].

Whereas water stress decreases the number of leaves, chlorophyll contents, grain yields, WUE, while using polymers 2.25-3 g kg^{-1} have shown the significant effects of the water stress and also increased the irrigation period[30]. Using 15 kg ha^{-1} polymer shown the best result mixed with NPK 150 kg ha^{-1}, similar with 300 kg ha^{-1} NPK alone, thus polymers improve the use efficiency of the pesticides, herbicides and fertilizers[31].

Not found any literature review on the usage of polymer with NPK and their effect on the production of maize in Thailand, therefore this study was conducted to evaluate the influence of integrated nutrients managements (INM) and usage of polymer mixed with NPK, their effects on soil fertility and productivity on maize (*Zea mays* L.) cv. TS-1004.

MATERIALS AND METHODS

Practical site: This research was carried out at the greenhouse of Agronomy Department, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand, during the rainy season of 2017.

Latitude of the Thailand, 13°45″14′N, longitude 100°30 05 E, latitudes decimal degrees (13.75398900), elevation around 12 m (39 ft) from the see level and annual rainfall 1611.7 mm (60).

Experimental layout: Experiment was conducted in Randomized Complete Block Design (RCBD) with four replications. The experiment was done in the pots experiment under greenhouse environmental controlled condition. Each pot was filled by 20 kg of loamy soil and kept at a distance of 30 and 75 cm between pots. The nitrogen, phosphorus and potassium fertilizers were used at the rate of 120:60:40 kg ha^{-1}, respectively. The compost fertilizer (312.5 kg acer^{-1}) and super absorbed polymer (312.5 kg ha^{-1}) were incorporated into the soil as source of soil supplements (modified method by Islam *et al.*[31]). The experimental treatments were applied as following:

T_1 : Soil mixed with nitrogen fertilizer
T_2 : Soil mixed with potassium fertilizer
T_3 : Soil mixed with phosphorus fertilizer
T_4 : Soil mixed with nitrogen, phosphorus and potassium fertilizer (NPK)
T_5 : Soil mixed with compost
T_6 : Soil mixed with super absorbed polymer (Polymer)
T_7 : Soil mixed with NPK and compost
T_8 : Soil mixed with NPK polymer
T_9 : Control (without fertilizer and soil supplements)

Plants were watered by once a day interval to keep the soil available water content not lower than 60%. All experimental units' were applied fertilizer at the rate which was mentioned above treatments by every 15 days intervals for three times (7, 22 and 37 days after planting). Morphological and physiological characteristics, yield parameters, harvest index and water used efficiency were recorded by following methods.

Physiological parameters: Plant height, LAI (Leaf area index) and CGR (Crop growth rate) were determined according to the method by Khaliq *et al.*[32], Simic *et al.*[33] and Williams[34]. LAI (Leaf area index) and CGR (Crop growth rate) were calculated by the following equation:

$$\text{LAI} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Ground area per plant (cm}^2\text{)}}$$

$$\text{CGR} = \frac{\text{W2 - W1}}{\text{P(T2 - T1)}}\ (\text{gm}^{-2}\ \text{day}^{-1})$$

Cobs parameters i.e., cob girth, cob length, cob weight, 100 seed weight and total production were determined by the method by Khaliq *et al.*[32].

Harvest index (HI %) was determined according to the method[35]:

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

Water use efficiency (WUE kg ha^{-1} mm^{-1}) was measured by the method modified by Singh *et al.*[36]:

$$\text{WUE} = \frac{\text{Total dry matter (kg ha}^{-1}\text{)}}{\text{Used water in season (mm)}}$$

The physiological parameters such as plant height, leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) were evaluated at 20, 40, 60 and 90 DAS (Days after the sowing). Cob girth, cob length, cob weight and yield parameters (100 seed weight and total production) were measured after harvesting.

Statistical analysis: The analysis of variance (ANOVA) one way was used to analyze the significant of all collected data. Least Significant Difference (LSD) was used to analyze for mean comparison between treatments and their interaction, except flow cytometer data. The ANOVA was used to compare for significantly different at $p<0.05$. The data analyses were performed and used statistical tool statistic version 08.

RESULTS AND DISCUSSION

Plant height (cm): Plant height reflects the vegetative growth behavior of crop plants to applied inputs. The average plant height was studied in all 9 treatments at different growth stages (20, 40, 60 and 90 DAS). A significantly highest plant height of maize was found in T_8 than all the other treatments during the all growth stages (Table 1). The plant height of maize crop in this study was found similar with the literature[37]. The positively variation in traits is due to the use of recommended dose of fertilizer (RDF %), combine with polymer, while the negative variation between the different treatments is due to the combination of agriculture inputs, although environmental factors and location affects were under the control conditions.

Leaf area index (LAI): Leaf area index is an indication to express the efficient and balance use of nutrients. It expresses the capacity of plant to trap solar energy for photosynthesis.

Table 1: Plant height (cm) with in treatments in different growth stages

Treatments	20 DAS	40 DAS	60 DAS	90 DAS
T_1	64.85 ± 2.33^{e}	142.00 ± 2.83^{d}	148.10 ± 2.97^{e}	162.5 ± 10.61^{d}
T_2	79.25 ± 2.8^{cd}	157.50 ± 3.54^{cd}	167.25 ± 4.31^{cd}	157.5 ± 10.61^{d}
T_3	90.00 ± 2.12^{bc}	194.00 ± 8.5^{a}	216.55 ± 9.3^{ab}	227.5 ± 24.8^{bc}
T_4	89.85 ± 11.53^{bcd}	189.60 ± 13.3^{a}	217.30 ± 4.7^{a}	255.0 ± 14.2^{ab}
T_5	76.50 ± 2.12^{de}	158.50 ± 2.12^{cd}	202.85 ± 11.11^{b}	167.5 ± 3.52^{d}
T_6	81.65 ± 7.99^{bcd}	145.50 ± 2.12^{cd}	$157.50\pm4.7d^{e}$	155.0 ± 7.1^{d}
T_7	92.85 ± 2.05^{b}	184.50 ± 6.4^{ab}	227.45 ± 4.6^{a}	215.0 ± 21.22^{c}
T_8	$127.85\pm3.32^{a*}$	$204.45\pm21.99^{a*}$	$229.55\pm5.02^{a*}$	$260.0\pm14.2^{a*}$
T_9	89.80 ± 9.2^{bcd}	164.00 ± 1.42^{bc}	178.10 ± 2.97^{c}	144.0 ± 1.42^{d}
Mean	88.067	171.12	193.85	193.78
CV	6.75	5.52	3.15	7.2
LSD	*	ns	ns	ns

Table 2: Leaf area index (LAI %) and crop growth rate (CGR; g^{-2} day^{-1}) within treatments in different growth stages

	LAI(%)				CGR (gm^{-2} day^{-1})			
Treatments	20 DAS	40 DAS	60 DAS	90 DAS	20 DAS	40 DAS	60 DAS	90 DAS
T_1	$0.27\pm(0.05)^{cd}$	$0.36\pm(0.049)^{b}$	$0.51\pm(0.043)^{c}$	$1.55\pm(0.1)^{c}$	$1.10\pm(0.021)^{d}$	$1.30\pm(0.043)^{c}$	$0.61\pm(0.078)^{g}$	$9.78\pm(0.93)^{de}$
T_2	$0.28\pm(0.01)^{cd}$	$0.43\pm(0.03)^{b}$	$0.58\pm(0.1)^{c}$	$1.35\pm(0.35)^{c}$	$0.97\pm(0.071)^{d}$	$1.97\pm(0.11)^{b}$	$1.52\pm(0.2)^{fg}$	$5.83\pm(0.6)^{e}$
T_3	$0.41\pm(0.071)^{b}$	$0.97\pm(0.021)^{a*}$	$1.04\pm(0.37)^{b}$	$2.80\pm(0.43)^{b}$	$2.03\pm(0.4)^{bc}$	$3.30\pm(0.21)^{a*}$	$3.38\pm(0.74)^{e}$	$26.80\pm(1.38)^{c}$
T_4	$0.40\pm(0.034)^{bc}$	$0.85\pm(0.043)^{ab}$	$0.99\pm(0.043)^{b}$	$2.80\pm(0.57)^{b}$	$2.48\pm(0.11)^{b}$	$2.93\pm(0.1)^{a}$	$7.40\pm(0.3)^{c}$	$33.62\pm(2.7)^{b}$
T_5	$0.28\pm(0 .047)^{bcd}$	$0.49\pm(0.12)^{ab}$	$0.58\pm(0.1)^{c}$	$1.60\pm(0.3)^{c}$	$1.13\pm(0.3)^{d}$	$0.76\pm(0.2)^{d}$	$4.70\pm(0.57)^{d}$	$11.09\pm(2.7)^{d}$
T_6	$0.24\pm(0.011)^{d}$	$0.40\pm(0.085)^{b}$	$0.43\pm(0.05)^{c}$	$0.81\pm(0.3)^{c}$	$1.12\pm(0.43)^{d}$	$0.76\pm(0.2)^{d}$	$2.07\pm(0.1)^{f}$	$8.03\pm(1.22)^{de}$
T_7	$0.26\pm(0.011)^{d}$	$0.42\pm(0.064b$	$1.40\pm(0.1)^{a}$	$2.95\pm(1.2)^{b}$	$1.51\pm(0.22)^{cd}$	$1.43\pm(0.24)^{c}$	$11.98\pm(0.6)^{a*}$	$26.15\pm(0.72)^{c}$
T_8	$0.59\pm(0.11)^{a*}$	$0.82\pm(0.065)^{ab}$	$1.53\pm(0.2)^{a*}$	$4.10\pm(0.3)^{a*}$	$3.09\pm(0.3)^{a*}$	$3.20\pm(0.43)^{a}$	$10.93\pm(0.7)^{b}$	$49.38\pm(3.75)^{a*}$
T_9	$0.24\pm(0.1)^{d}$	$0.56\pm(0.12)^{ab}$	$0.57\pm(0.1)^{c}$	$0.96\pm(0.1)^{c}$	$1.30\pm(0.14)^{d}$	$1.74\pm(0.23)^{bc}$	$2.47\pm(0.18)^{ef}$	$6.62\pm(0.51)^{e}$
Mean	0.329	0.586	0.826	2.073	1.634	1.931	5.005	19.695
CV	17.86	38.61	17.83	18.89	15.61	11.15	9.02	9.81
LSD	*	ns	*	*	*	*	*	*

In Table 2 at 20 DAS the average range of LAI was (0.594- 0.235), however the maximum LAI was produced by T_8 (NPK+Polymer), (0.594) and the minimum LAI was produced by T_9 (0.235). At 40 DAS T_3 gave highest LAI (0.965), followed by T_8 (0.82), whereas the lowest LAI was observed at T_1. At 60 and 90 DAS T_8 gave significantly higher values of LAI which was 1.525 and 4.1, respectively, whereas the lowest values of LAI was observed at T_6 at both stages, respectively. This highest 1.525-4.1 in T_8 might be due to the existence of essential nutrients in root zone of the plants[38-39].

Crop growth rate (CGR, g^{-2} day^{-1}): The phenotype differed significantly for CGR (crop growth rate) (Table 2). At 20 DAS higher values of CGR were recorded at T_8 (3.09 g^{-2} day^{-1}), whereas the lower values were observed at T_2 (0.97 g^{-2} day^{-1}). However, at 40 and 60 DAS the CGR values were observed higher in T_3 (3.3 g^{-2} day^{-1}) and T_7 (11.98 g^{-2} day^{-1}), respectively, while the lowest CGR values were found in T_6 (0.755 g^{-2} day^{-1}) and T_1 (0.605 g^{-2} day^{-1}), respectively.

Interestingly at 90 DAS the CGR values were recorded significantly highest in T_8 (49.38 g^{-2} day^{-1}), which was literally two times higher than the second highest CGR values, whereas the lowest CGR values was observed at T_2 (5.826 g^{-2} day^{-1}). The CGR in maize crop gradually increased along with growth stages, however, reached to maximum stage at flowering stage[40-41].

Net assimilation rate (NAR): Net assimilation rate of the mentioned treatment were extensively studied at all four growth stages (20, 40, 60 and 90 DAS). At 20 DAS T_8 gave higher values (6.65), followed by T_7 (5.25), whereas at the same stage the lowest NAR was seen at T_2 (3.8) and T_6 (3.85), respectively. At 40 DAS the result shown the highest NAR which was significantly higher than the rest of the sample observed at T_8 (5.49), although it was higher than the 20 DAS NAR, whereas T_7, T_3 and T_4 gave closer similar to each other NAR at the same stage. At 60 and 90 DAS result depicted that T_8 gave significantly higher NAR 9.38 and 11.4, respectively, it was clearly observed that T_8 gave the highest NAR at all stages, whereas the T_9 gave the least NAR rates at all four stages (Table 3). Net assimilation rate refers to the uptake level and use efficiency of nutrients in soil. The results have been showed the agreement with the finding of Luque *et al.*[38] and Stehli *et al.*[39]. NAR one of the execute sign for high yield of the maize crop. Higher NAR is the result of increased photosynthetic efficiency and better availability of the essential nutrients in sinks areas[41].

Table 3: Net assimilation rate NAR (g^{-2} day^{-1}) within treatments at different growth stages

Treatments	20 DAS	40 DAS	60 DAS	90 DAS
T_1	4.07 ± 1.3^{ab}	4.90 ± 1.8^{b}	5.62 ± 0.7^{bc}	6.33 ± 0.9^{bc}
T_2	3.80 ± 0.5^{c}	4.22 ± 0.02^{bc}	4.80 ± 0.3^{cd}	5.41 ± 0.7^{bc}
T_3	4.45 ± 0.6^{bc}	4.91 ± 0.4^{b}	5.04 ± 1.4^{b}c	9.24 ± 0.4^{b}
T_4	4.75 ± 0.5^{bc}	4.88 ± 0.9^{bc}	7.88 ± 0.5^{b}	9.04 ± 2.9^{bc}
T_5	4.00 ± 0.4^{bc}	4.35 ± 0.3^{bc}	8.63 ± 0.5^{b}	8.89 ± 0.4^{bc}
T_6	3.85 ± 0.5^{cc}	3.95 ± 1.3^{bc}	5.60 ± 0.7^{bc}	10.37 ± 2.2^{b}
T_7	$5.25\pm0.\ 8^{b}$	4.95 ± 0.6^{b}	9.04 ± 0.4^{b}	9.85 ± 0.5^{b}
T_8	$6.65\pm0.1^{a*}$	$5.49\pm1.3^{a*}$	$9.38\pm1.2^{a*}$	$11.40\pm0.1^{a*}$
T_9	3.13 ± 0.9^{c}	3.54 ± 0.7^{c}	3.65 ± 0.5^{d}	3.98 ± 1.1^{c}
Mean	4.654	3.379	5.769	7.777
CV	14.59	11.85	9.22	18.56
LSD	*	*	*	*

Table 4: Cob's and yield parameters within treatments after harvesting time

Treatments	Cobs girth (cm)	Cobs length (cm)	Cobs weights (g)	100 seed weight (g)	Seed (kg ha^{-1})
T_1	3.27 ± 5.9^{bc}	5.84 ± 2.02^{cd}	24.10 ± 11.2^{c}	20.03 ± 0.12^{d}	1056.20 ± 25.15^{e}
T_2	3.43 ± 1.1^{c}	7.70 ± 2.4^{c}	22.40 ± 7.8^{c}	17.00 ± 0.25^{d}	923.20 ± 44.12^{g}
T_3	3.98 ± 3.6^{ab}	13.70 ± 0.6^{b}	77.02 ± 13.3^{b}	21.60 ± 1.23^{c}	3206.10 ± 33.2^{d}
T_4	4.38 ± 2.5^{a}	16.00 ± 1.04^{a}	119.00 ± 21.82^{a}	28.00 ± 6.4^{ab}	5446.10 ± 13.12^{b}
T_5	3.53 ± 1.7^{bc}	6.30 ± 1.3^{cd}	23.50 ± 1.4^{c}	16.00 ± 12.3^{d}	1023.83 ± 22.3^{f}
T_6	3.06 ± 4.1^{c}	4.70 ± 0.3^{d}	14.00 ± 5.44^{c}	16.64 ± 16.05^{d}	878.60 ± 24.6^{i}
T_7	4.37 ± 4.2^{a}	16.84 ± 2.3^{ab}	106.00 ± 35.6^{a}	26.50 ± 22.3^{b}	4665.10 ± 49.5^{c}
T_8	$4.50\pm0.7^{a*}$	$18.20\pm0.8^{a*}$	$109.64\pm4.1^{a*}$	$28.50\pm18.5^{a*}$	$5847.50\pm25.4^{a*}$
T_9	3.12 ± 3.9^{c}	6.00 ± 2.65^{cd}	21.00 ± 1.4^{c}	21.006 ± 23.5^{d}	574.22 ± 42.13^{h}
Mean	37.384	10.537	59.451	21.697	2628.40
CV	9.22	16.05	26.02	0.01	0.22
LSD	*	*	*	*	*

Additionally, the result depicted that all the above mentioned physiological parameters has positive correlation with biomass and grain yield production, which were recorded for biomass with LAI (r = 0.47), RGR (r = 0.398), CGR (r = 0.999) and for NAR (r = 0.684), however the correlation between the physiological parameters and grain yield were LAI (r = 0.699), RGR (r = 0.0282), CGR (r = 0.848) and with NAR (r = 0.405). it was also observed that both of yield parameters (Biomass+grain yield) had weak but positive correlation with RGR, while with the rest of parameters it had strong positive correlation, which may be the reason of causing high yield.

Cob parameters: In the current study, it was observed that using chemical fertilizers without moisture content in root zone of the plants nothing in dry land or arid and semi-arid reigns. In T_8 (NPK+polymer) gave the positive result with using NPK combine with polymer for being moisture content in root zone, shown the positive result (Table 2 in physiological status), (Table 4), cobs and yield parameters, T_8 have shown the highest value in all parameters (Table 1-3), for cobs parameters such as cob weight (109.64±4.1 g), 100 seed weight (28.5 g) and expected yield ha^{-1} (5847.5 kg).

Water use efficiency (WUE) (kg ha^{-1} mm^{-1}): Water use efficiency is one of the reliable indicators for good performance and high yield of the crops, which is related in the existence of the water content at the root zone of the crops. The water use efficiency was thoroughly studied in all treatments along with T_9. It was found in the similar trend and followed by T_8 showed significantly higher values (22.8) of the water use efficiency. It means the T_8 used the same water level in all growth stage, whereas produced the highest production as compare with others treatments (Fig. 1). To study the water use efficiency used the method modified by Singh *et al.*[36].

Harvest index (%) (HI): Harvest index (%) of all treatments were studied the data obtained from total biological yield was used to calculated the harvest index out of all treatments the highest harvest index was recorded at T_8 (0.68%), followed by T_7 (0.62%), (Fig. 2), whereas the lowest harvest index measured in T_9(0.33%).

The current study has shown that using polymer in the combination of recommended dose of chemical fertilizers (RDF %), gave good results and increased vegetative and reproductive growth in all growth stages. Using the polymers mixed with RDF (%), improve the physical properties of the soil and water holding capacity (WHC), 400 times more than their weight which ultimately results in better growth and high production[42]. It was also reported that acidity, salinity, non-availability of the nutrients are the characteristics of the poor soil which further decrease the availability of the water to plant[43].

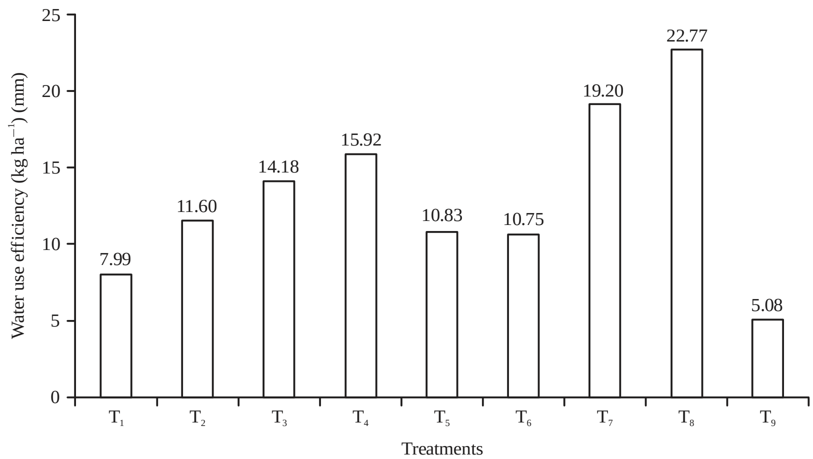

Fig. 1: Water use efficiency (WUE) within treatments at different growth stages

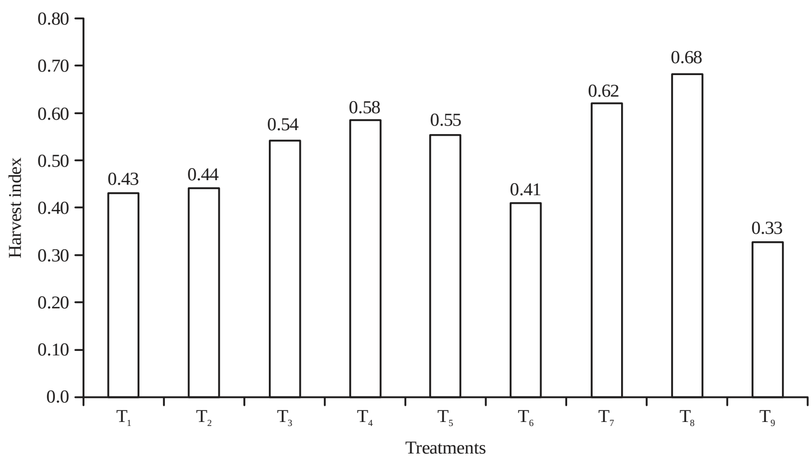

Fig. 2: Harvest index (HI %) within treatments

Additionally soil moisture availability is very important for crop growth and high yield productions, more function of the water linked to plant and soil, the structural constituent of plant cell, source of essential elements (O, H), which are required to synthesis carbohydrates during the photosynthesis, the agent of solvent to allow the metabolic reactions and making nutrients available, increasing the up taking level and improve the transportation of the manufactured in to various part of the plants. Proper amount of water accessible to plants needs to less amount of energy (tension 1/100 or 0.01 centibar), being saved energy converted to yield and increasing water productivity along yield production, which just possible by using carboxylic groups agents (Polymer and organic materials), retain the water in root zone. Whereas in root zone the water is less or useless for plants it will needs to more energy to extract the water from the soil, although the tension energy using for water extraction greater than overcome, they will die and handled yield will be less during the field capacity tension force around -10 to -20 centibars[44].

CONCLUSION

The critical evaluation and screening of genotype depend on the different type of uses chemical fertilizers mixed with compost source of the organic matter in the soil, along with polymer which is also called hydrophilic, that improves water use efficiency with nutrients too. It was concluded that out of nine treatments, T_8 was found physiologically more efficient then rest of others treatments. T_8 found to be superior in respect to plant height, leaf area index (LAI), crop growth rate (CGR), NAR (g^{-2} day^{-1}), cobs parameters (cob girth (cm), cob length (cm), cob weight (g), yield parameters such as (100 seed weight (g), yield production kg (ha), the prominent maize crop of the T_8 higher in water use efficiency and in harvesting index (HI) as well.

SIGNIFICANCE STATEMENT

This study focused about the water scarcity all over the world, which is the basic need to plant and one of the vital substances for sustainable agriculture to feed the increasing rate of population in future especially developing country. The study indicated that implementation of super absorbed polymer mixed with NPK fertilizer could play a better role to improve the soil condition and increase the productivity of maize. This may be due to its better of water holding capacity for longer period of time which could be beneficial for drought affected areas.

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