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Research Article

Effect of Polymer and Compost on Growth and Yield of Cauliflower (*Brassica Oleracea*) under Different Moisture Regimes

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ABSTRACT

Water being an essential component for plant growth and development, its scarcity possesses serious threat to crops around the world. Climate change and global warming are increasing the temperature of earth hence becoming an ultimate cause of water scarcity. It is need of the day to use potential soil amendments that could increase the plants resistance under such situations. The study was planned to enhance the water use efficiency using chemical and organic amendments under wire house conditions. Polyacrylamide and compost were used to improve the WUE and growth of *Brassica Oleracea* (Cauliflower). Experiment was comprised of four treatments including control, polymer, compost and combination of polymer and compost. Three irrigation levels i.e. 35%, 75% and 100% of field capacity were applied. Each treatment was replicated thrice and complete randomized design with factorial arrangement was used. Recommended dose of fertilizers was applied while water was applied according to calculations based on field capacity. The data relating the agronomic, chemical and physiological parameters was gathered before and after harvesting. In treatments having combination of compost and polymer maximum increment in plant height (91.81%), chlorophyll contents (84.38%), relative water content (53.41%), soil nitrogen (33.5%), soil phosphorous (37.35%), soil potassium (22.5%) and soil organic matter (90%) was noticed as compared to control. Maximum reduction in proline contents and electrolyte leakage was noticed as 35% and 73.02% respectively. It was concluded that application of compost and polymer improved the growth, yield and increased soil nitrogen, phosphorous and potassium availability under the water limited conditions.

Keywords: Water shortage, Compost, polymer, *Brassica Oleracea*

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INTRODUCTION

Climate of world has been started to vary for several years ago that caused severe ecological, communal and commercial crises for entire world population. Due to climate change average temperature of universe is increasing and pattern of rainfall is changing throughout the world. Impact of climate change are unequally dispersed between the world population and developing countries are more exposed to these impacts due to the lack of capability and resources (Thornton et al., 2008). Change in climate posed several adversarial effects to many sectors but threat to agriculture sector is most considerable (Seo et al., 2008). Most of world population particularly in developing countries rely upon agriculture for their survival and income. Agriculture is very susceptible to variation in weather and climate that give rise to the extreme weather conditions like drought, floods and storms (Dinar et al., 2008).

Climate change influence the availability of fresh water for agriculture activities by effecting pattern of rain fall, raising the temperature and enhancing the occurrence of drought (Kotir, 2011). During past few years, the occurrence and intensity of floods and drought is increased many folds due to climate change. Problem of water scarcity is further augmented by adulteration of water supplies and climate change (Res et al., 2011). Requirement of water for agriculture, energy and industrial sectors is enhanced many times owing to expansion of industries and ever-increasing population (Vadez et al., 2011). Drought is a meteorological phenomenon that caused the irregular and prolong deficiency of rainfall. Drought is considered as environmental calamity and is matter of concern for scientist of all field such as ecology, hydrology, meteorology, geology and agriculture (Rollins et al., 2013).

Occurrence of drought is very common in arid and semi-arid region like Pakistan where the limitation of rainfall diminished the growth and productivity of crop. Specific characteristic of these soils such as elevated infiltration rate, least water holding capability, excessive drying period and lower percentage of organic matter limits the productivity of crop (Yadav et al., 2010). In order to full fill the food requirement of world population that is increasing constantly there is need to adopt strategy that can increase the food production and improve irrigation efficiency. Deficiency of water during various drought periods is one of the major stresses that can reduce the production of crop (Lobell et al., 2007). In addition to harmful influence of water deficiency on quantity of yield, quality of crop is also badly affected by water scarcity (Narasimhan et al., 2005).

Various techniques have been used to mitigate the harmful impacts of drought stress including dispersal of manure, crop rotation and green manuring. Application of organic waste together with sewage sludge is one of the most preferred soil amendments. Use of sewage sludge is beneficial only when used in small proportion. Unessential use of sewage sludge increased the bioavailability of heavy metals up to dangerous level (Usman *et al.*, 2012). Other strategies which are ideal to lessen the negative effects of drought include the use of compost, different types of polymer, drought resistant varieties, altering the crop pattern (Venkateswarlu and Shanker, 2009). Compost is a rich source of organic matter and diminish the impact of drought stress by declining the formation of soil crust, surface runoff, modifying the structure and total porosity of soil as a result of these process hydraulic conductivity and water holding capability of soil improved (Hargreaves et al., 2008).

Compost improves the soil physical, chemical and biological properties and supplies nutrient to plant. Compost improves the quality and fertility status of soil by increasing the organic matter. Compost provide assistance to plant to survive during extreme weather conditions such as fluctuating supply of water, air and heat as a result of which crop yield increases. Addition of compost in soil decline the evaporation losses and enhance the water storage in soil under limited water supply (Adugna, 2016). Application of compost in combination with synthetic fertilizer is an integrated strategy that helps to maintain average crop yield. Compost mitigates the drainage of water below the root zone owing to its spongy property and helps to preserve the soil moisture under drought stress. In clayey soil compost increases the proportion of total pore space and minimize the chances of water logging by improving water drainage (Brown and Cotton, 2011).

Certain type of chemical compounds is used as soil conditioner which possess the remarkable hydrating characteristics and are found in both natural and synthetic form. These special types of chemicals perform a role of binding agent that modify the distribution of pores, increase the proportion of water stable aggregate and improves nutrient consumption capability of crop during drought stress. Polymer hydrogels have the capability to absorb large quantities of water and supplies water to plant according to their necessities. Synthetic polymers such as polyacrylate, rubber latex, polyurethane, polyacrylamide (PAM) and polyvinyl acetate have been extensively used to modify the soil structure and water conservation ability in coarse textured soil. Among all synthetic polymer, PAM has greater efficiency to mitigate the crust formation, modify the soil structure, enhance infiltration of water, hydraulic conductivity, soil aeration and minimize the loss of soil (Kim et al., 2015).

Utilization of PAM as soil conditioner has many advantageous influences on plant development as it enhances the availability of water to plant and improves WUE during drought stress (Asgharipour, 2011). Polyacrylamide is very costly, and its direct utilization is proscribed owing to certain essential application prerequisite (Goebel et al., 2005). Previous research indicated that use of PAM with crop straw is very effective to enhance the crop yield, water conservation ability of soil and lessen the evaporation losses (Liang et al., 2009). Under drought condition utilization of PAM along with organic material such as compost has very significant effect to increase the water use efficiency and availability of water to plant.

Cauliflower (Brassica oleracea) is the most valuable vegetable of family Brassicaceae. White curd of Cauliflower is edible, and its leaves are preferably used in curry. Curd extract of cauliflower is very effective for the treatment of scurvy disease and used as blood purifier agent. Cauliflower comprises of numerous phytochemical which are very valuable for human health (Golabi et al., 2004). Extract of cauliflower comprise of carotenoids, isothiocyanates, ascorbic acid, flavonoids, indoles and tocopherols which are very effective to check the initiation and promotion of carcinogenesis. Sometimes, stalks and leaves of cauliflower are used as fodder (Sharma et al., 2004). Cauliflower has high nutrition value due to high water content, dietary fiber, vitamin C, foliate and lower fat content. 100 g of edible portion of Cauliflower can provide 25 kcal energy, 5 g carbohydrate, 2.4 g sugar. 2.5 g dietary fiber, 2g protein and 0 g fat (Pennington et al., 2007).

Cultivation of cauliflower is cost effective and small hold farmers can easily cultivate it. Among top ten cauliflower producing countries Pakistan is also included and in 2011 total cauliflower production was recorded as 0.2 MT/year (Odegard et al., 2014). Cauliflower is very sensitive to deficiency of water during its all-growth stages. As the plant exposes to drought stress various physiological and chemical changes arises in plant that disturb the normal growth and development. During the drought stress development of cauliflower ceases at all and premature heading starts. As a result of which growth of cauliflower is imperfect that leads to reduction in yield of crop (Wu et al., 2012).

The main objective of this research was;

To evaluate the combined effect of compost and polyacrylamide on growth of cauliflower under water deficit condition.

MATERIALS AND METHODS

A pot study was executed in the wire house of ISES, UAF through the duration of 2019-2020 to estimate the influence of polyacrylamide and compost on development and production of cauliflower under the different moisture regimes. The experiment was planned according to completely randomized design with two factors and prior to onset of experiment soil sample were obtained in random way to perform the pre-analysis of soil.

Layout Plan

The pot experiment was planned according to completely design with two factors. The experiment comprised of twelve treatments with three replicates of each treatment. According to treatment plan, impact of compost and polyacrylamide was evaluated separately and in combination of both treatments. Polyacrylamide and compost were separately applied at rate of 10 g per kg of soil and combination of both treatments was applied at rate of 5 g per kg of soil. Detail of treatment plan is given below in table 1.

Table 1. Treatment plan of different compost and polymer applied in experiment.

Treatments	35% moisture	75% moisture	100% moisture
T_1 (Control)	-	-	-
T_2 (PAM)	@ 1%	@ 1%	@ 1%
T_3 (CM)	@ 1%	@ 1%	@ 1%
T_4 (PAM + CM)	1:1	1:1	1:1

Data relating to physiology of plant such RWC, proline contents, electrolyte leakage, and proportion of chlorophyll was estimated at the plant development stage. After the reaping of crop, data pertaining to plant height, fresh and dry weight of plant, fresh and dry weight of root and yield of crop was evaluated. For calculation of concentration of nitrogen, potassium and phosphorous in root and shoot of plant chemical analysis was also performed.

Calculation and Maintenance of Specific Moisture Concentration

Specific moisture concentrations of 35%, 75% and 100% were calculated and maintained by estimation of the ability of soil to supply water to plant which is also called plant available water. Plant available water was determined by subtracting the value of permanent wilting point (-15 bars) from value of field capacity (33 bar) of soil which was filled in pots. Value of permanent wilting point (PWP) and field capacity (FC) was determined by running the saturated soil samples in pressure plate extractor at pressure of -15 bar and 33 bar respectively (Janz *et al.*, 2001). Plant available water was determined by following equation.

$$\text{Plant available} = \text{FC} - \text{PWP}$$

After estimation of plant available water capacity of soil, to maintain the specific moisture level the amount of water required was calculated by unity method. Plant available water capacity of soil that was filled in pots was 60%. From this plant available water percentage, we calculated amount of irrigation water to maintain the moisture level of 35%, 75% and 100% by unity method. Amount of irrigation water to maintain the moisture level of 35%, 75% and 100% was 58.33 ml, 125 ml and 166.66 ml respectively.

Soil Collection and Preparation

Soil was accumulated from the research area of ISES, UAF with the aid of auger. After collection soil was assorted properly and filled in polythene bag to bring in the wire house of ISES, UAF. In wire house soil was spread on clean plastic sheet to dried it in air properly, grinded with assistance of grinder and finally filtered through the 2 mm sieve to acquire a composite soil. Polythene bags were used to line the inner walls of pots to evade the leaching of water. After that each pot was filled with 7 kg soil to start the experiment. Some soil was brought in the laboratory to perform the physio-chemical analysis of soil.

Collection of Cauliflower Seeds and Nursery Raising

For raising the cauliflower nursery, seeds were obtained from agriculture market Dijkot road, Faisalabad. Iron tray was used to sow the cauliflower nursery.

Nursery Transplanting and Harvesting

When the seedling of cauliflower was at three leaves stage then it was transplanted to pots containing 7 kg soil. In every pot three seedling were transplanted.

Agronomic Parameters

Plant height (cm) and root length (cm) was recorded when crop was harvested at maturity stage. Plant height was measured from tip of leaves to point where area of plant root started. Root length was measured with the help of plastic measuring tape. Leaf area (cm^2) was recorded using Grid Counting Method by putting leaves of graph. Plant fresh weight (g), Plant dry weight (g), Root fresh weight (g), Root dry weight (g) was calculated with help of electrical balance after the harvesting of crop.

Physiological Parameters

After 60 days of transplantation of nursery, relative water content (%) upper most leaf of cauliflower was taken for estimation of relative water content using method described bt Yamasaki et al., 1999. Chlorophyll contents were recorded using SPAD. Proline contents were estimated following procedure described by Bates et al. (1973). Determination of electrolyte leakage was measured using conductivity meter and its calibration was done according to instruction proposed by manufacturer (Latrach et al. 2014). Photosynthetic yield (µmol m-2 s-1) was measured using photosynthetic yield analyzer.

Plant Analysis

Fluorescent rate (µmol m^{-2} s^{-1}) and Photosynthetic active radiation (PAR) (µmol m^{-2} s^{-1}), Electron transport rate (ETR) (µmol m^{-2} s^{-1}) were measured with the help of photosynthetic yield analyzer that automatically measure the fluorescence rate along with photosynthesis rate. Chapman and Parker, (1961) procedure was used to estimate the nitrogen concentration in the plant samples. Spectrophotometer was used to measure phosphorus in plant by using standard curve. Flame photometer was used to determine the K concentration

Analysis of soil

Saturation percentage was estimated by using the formulae listed below.

$$S.P\ (\%) = \frac{\text{Loss in wt. of soil}}{\text{weight of oven dry soil}} * 100$$

To estimate the organic matter present in soil sample Walkley Black method (1947) was followed. Readings for extractable phosphorous and potassium was recorded using method described by (Olsen et al., 1954). To evaluate the extractable potassium, 5 g of grinded soil sample and 30.

Statistical Analysis

Results concerning to all parameters attained by all physical and chemical analysis was recorded watchfully and by using Fisher method of analysis of variance (Steel *et al.,* 1997) was statistically analyzed with help of software statistix 8.1. Least significance test (LSD) was used to analyze the treatment mean.

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RESULTS

Influence of polyacrylamide and compost on development, production, chlorophyll content, electrolyte leakage, electron transport rate, fluorescent rate, proline content in plant samples were estimated at growth stage and proportion of NPK in both soil and plant samples were estimated after the harvesting. Consequences about various parameters are elucidated below. The results of analysis of variance for morphological and physio-biochemical characters are represented in table 2. It can be seen that all the characters got highly significant variations with changing moisture and applied treatments of compost and polymer. But the interaction of moisture and applied treatments is non-significant in some characters viz. PAR, AY, RFW, RDW and PPC. The significant variations showed by the characters shows significant of research work for creation of variability.

Table 2. Analysis of variance for different morphological and physio-biochemical characters under study.

Character	MSS value (Moisture)	MSS (Treatment)	MSS (Treatment Moisture)
CC	68.99**	1462.71*	1.63*
RWC	2271.57**	448.70**	49.18**
PC	226.33**	8795.71**	3.20**
EL	105.99**	4478.05**	1.64
PAR	3829**	385992**	244**
FR	2349**	132875**	42**
ETR	1913.36**	51690.0**	143.25**
PY	0.08 **	0.25305**	0.002*
AY	27.44**	204.02**	0.11
PH	37.19**	531.69**	1.779**
LA	1610.2**	93327.1**	108.0**
PFW	1483.1**	60925.2**	102.2**
SDW	31.75**	433.66**	0.41**
RL	55.92**	237.97**	2.63**
RFW	75.51**	928.469**	0.703
RDW	1.48**	16.53**	0.02
SNC	0.00006**	0.00120**	0.00004**
SPC	1.27736**	3.02305**	0.30213**
SKC	152.201**	584.428**	15.628**
PNC	0.04127**	0.20319**	0.01354**
PPC	0.22716**	0.04487**	0.00492
PKC	9.1207**	32.8773**	0.00492**

P value 0.01-0.05= significant =*, P value <0.01= highly significant =** P value > 0.05= non-significant = no esteric

CC=chlorophyll content, RWC=relative water content, PC=proline contents, EL=electrolyte leakage, PAR= photosynthetic active radiation, FR=fluorescent rate, ETR=electron transport rate, PY=photosynthetic yield, AY=actual yield, PH=plant height, LA=leaf area, PFW=plant fresh weight, SDW=shoot dry weight, RL=root length, RFW=root fresh weight, RDW=root dry weight, SNC=soil N concentration.SPC=soil phosphorous concentration SKC=soil K concentration, PNC=plant nitrogen concentration, PPC=plant phosphorous concentration, PKC=plant potassium concentration.

The mean data of all morphological and physio-biochemical characters are represented in the form of graphs in figure 1, 2, and 3. chlorophyll content, relative water content, photosynthetic active radiation, fluorescent rate, electron transport rate, photosynthetic yield, actual yield, plant height, leaf area, plant fresh weight, plant dry weight, root length, root fresh weight, root dry weight, soil phosphorous concentration soil K concentration, plant nitrogen concentration, plant phosphorous concentration, plant potassium concentration showed increasing trend in control, T1 (polymer) and T2 (compost) and their levels also. The mean values for these characters increased with increasing polymer and compost treatment and also their levels. Proline and electron leakage showed decreasing trend in control, T1 (polymer) and T2 (compost) and their levels also. The mean values for these characters decreased with increasing polymer and compost treatment and also their levels.

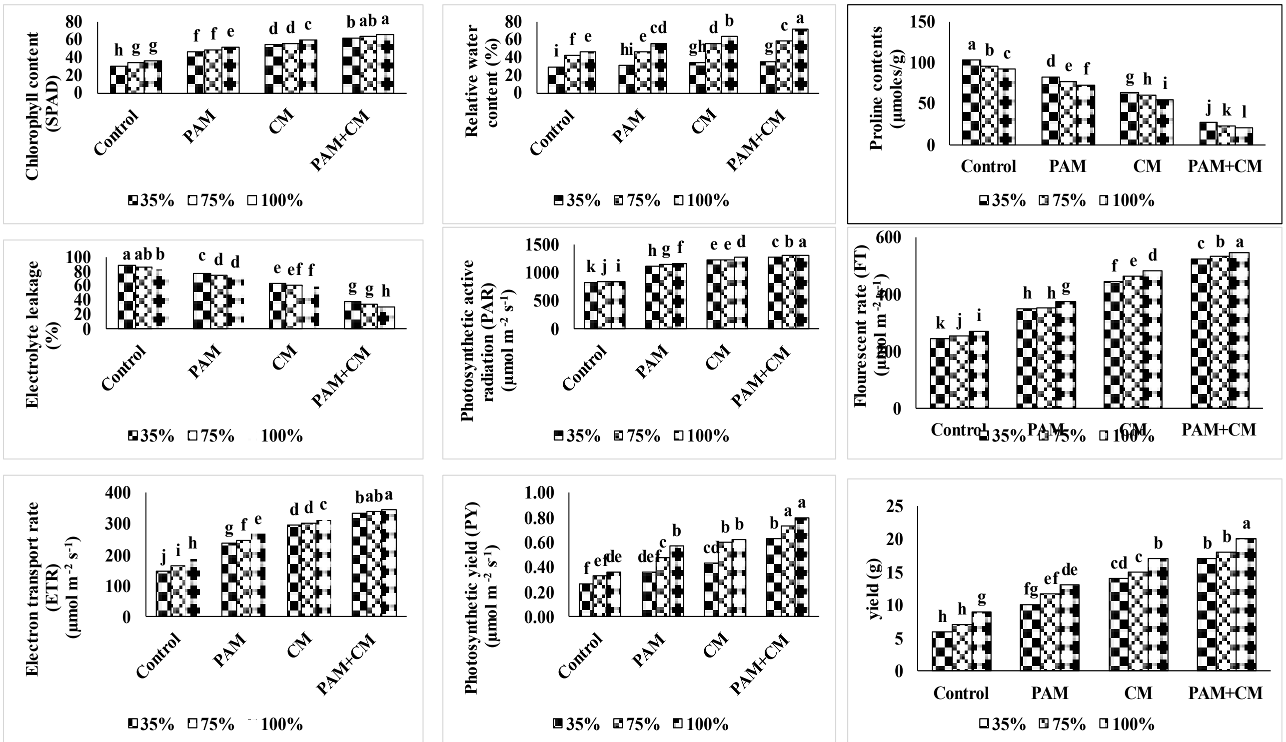

Figure 1. The treatment wise performance of soil and plant parameters under controlled and application conditions. PAM=polyacrylamide, CM=Compost, PAM+CM= polymer and compost.

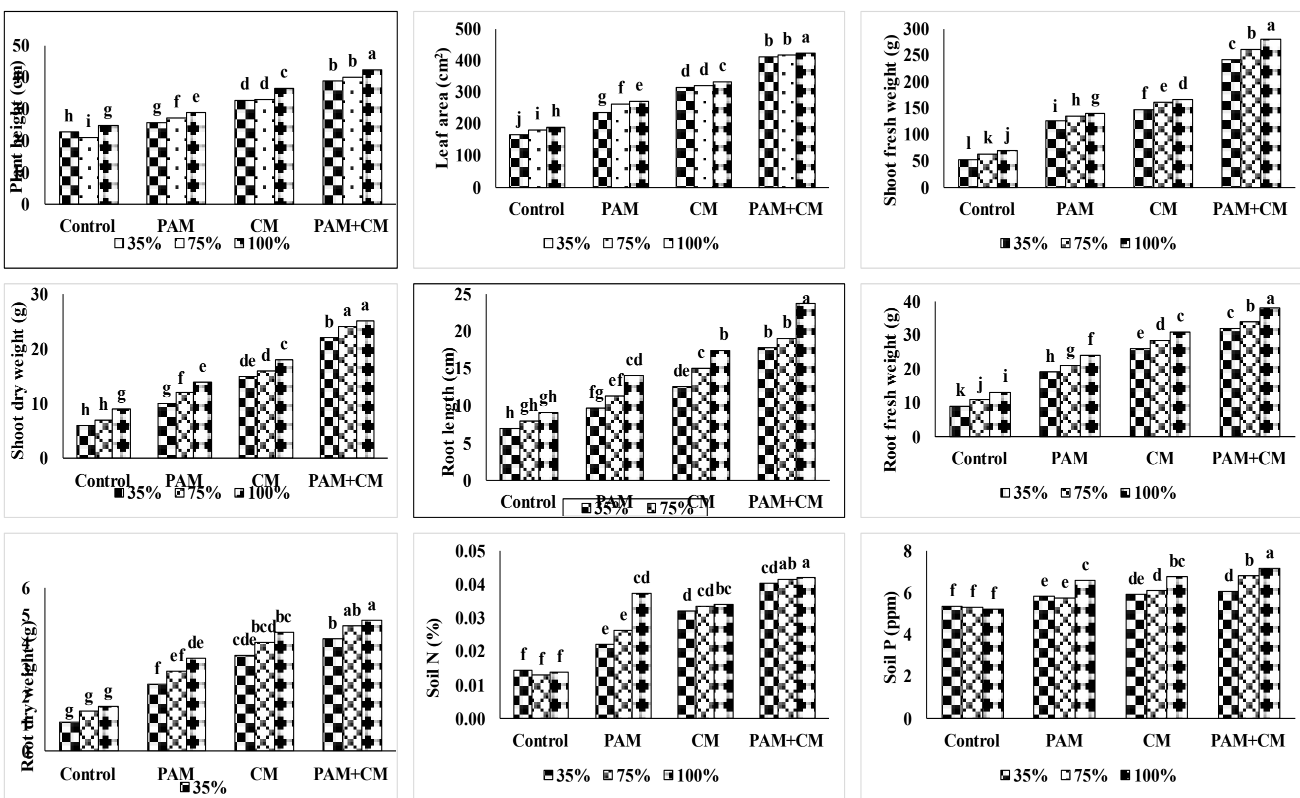

Figure 2. The treatment wise performance of soil and plant parameters under controlled and application conditions PAM=polyacrylamide, CM=Compost, PAM+CM= polymer and compost.

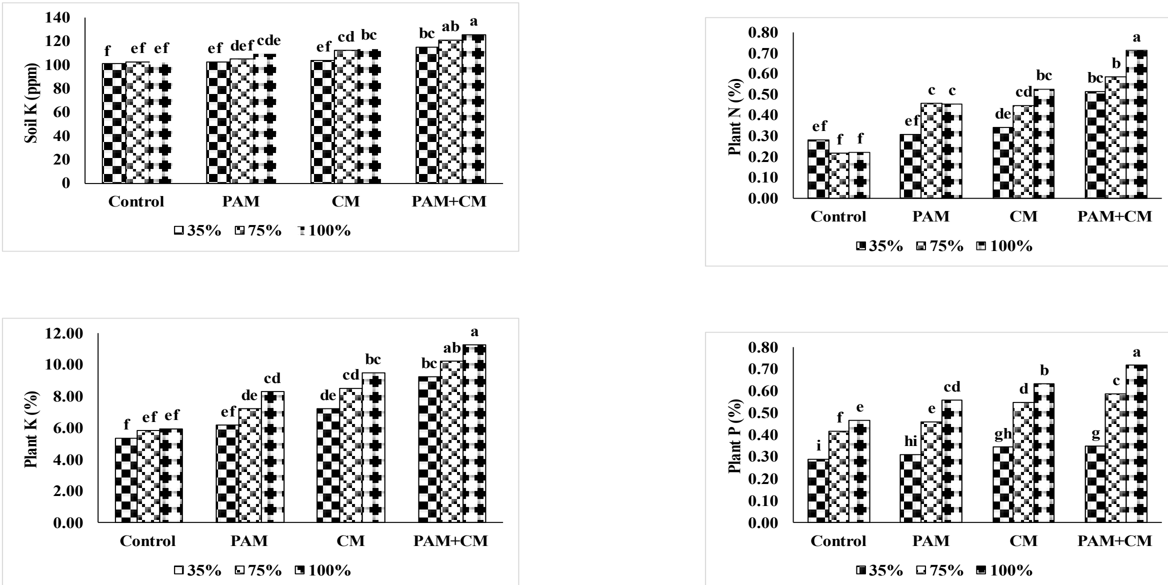

Figure 3. The treatment wise performance of soil and plant parameters under controlled and application conditions PAM=polyacrylamide, CM=Compost, PAM+CM= polymer and compost

DISCUSSION

Application of compost and polyacrylamide is an effective strategy to enhance the quality and fertility status of soil and water use efficiency of crop. Compost provide assistance to plant to survive during extreme weather conditions such as fluctuating supply of water, air and heat as a result of which crop yield increases. Compost mitigates the drainage of water below the root zone owing to its spongy property and helps to preserve the soil moisture under drought stress. Utilization of PAM as soil conditioner enhances the availability of water to plant and improves WUE during drought stress (Asgharipour, 2011). Under drought condition utilization of PAM along with organic material such as compost has very significant effect to increase the water use efficiency and availability of water to plant.

Wei *et al.* (2011) in his research evaluated that PAM application increased the plant heigh and root length due to improvement in water availability to plant that were similar to present findings. Hosh et al. (2018) examined that due to application of compost and polyacrylamide in combination plant height and root length was maximum in comparison to other treatments owing to better supply of nutrient and water to plant.

Plant fresh weight, root-shoot fresh and dry weight and yield increased under the influence of compost and polyacrylamide. Increased in yield and other parameters may be due to improvement in soil organic matter, reduction in evaporation, supply of water and nutrient according to requirement of crop. Yamato et al. (2006) in his study revealed that plant growth and yield increased after the application of compost owing to improvement in soil properties, soil organic matter and better availability of nutrient. Lee et al. (2008) revealed that yield of crop and other growth and yield relating parameters increased after the application of polyacrylamide. Polyacrylamide increased yield owing to improvement in soil porosity and aeration which provide suitable condition for plant growth.

Wei et al. (2011) concluded that due to application of polyacrylamide leaf area and chlorophyll content increased in crop leaf. PAM enhanced that availability of water for crop growth and mitigate the adverse effect of temperature and transpiration. Hodges et al. (2006) reported that owing to spongy property of polyacrylamide more water and nutrient are available all the time for plant use as a result of which leaf area and chlorophyll content in plant leaf increased. Owing to enlarge surface area of leaf process of photosynthesis improved and more food is produced for plant growth and development.

Ai-Ping et al. (2011) examined that polyacrylamide reduced the loss of nutrients, reduce soil erosion and are beneficial to maintain the soil fertility status of soil. Akmal et al. (2019) concluded that due to application of compost microbial biomass increased in soil as result of which nutrient availability and nutrient status of soil improves.

CONCLUSIONS

The findings of this study highlighted the role of rhizobacterial strains in improving soil physicochemical properties and increasing wheat (*Triticum aestivum* L.) growth and yield. The rhizobacteria led to improved soil fertility by enhancing nutrient availability, organic matter, and soil structure. The positive effects on plant growth parameters, including biomass accumulation, root development, and grain yield, suggested that rhizobacteria can serve as effective biofertilizers in sustainable agriculture. Integrating rhizobacteria-based biofertilizers into modern agricultural systems can contribute to sustainable wheat production and improved soil health.

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AUTHOR CONTRIBUTIONS

All the authors contributed equally to this research.

COMPETING OF INTEREST

No conflicts of interest have been disclosed by the authors.

REFERENCES

Adugna, G. 2016. A review on impact of compost on soil properties, water use and crop productivity. *J. Agric. Food Chem.* 4: 93-104.

Ai-Ping, W., Fa-Hu, L., Sheng-Min, Y. 2011. Effect of polyacrylamide application on runoff, erosion, and soil nutrient loss under simulated rainfall. *J. Plant Nutr.* 29: 157–172.

Akmal, M., Maqbool, Z., Khan, K.S., et al 2019. Integrated use of biochar and compost to improve soil microbial activity, nutrient availability, and plant growth in arid soil. *Arab. J. Geosci.* 12: 1-10.

Asgharipour, M.R., Rafiei, M. 2011. The effects of land use on biomass and catabolic diversity of soil microbial communities. *Afr. J. Agric. Res.* 6: 4607-4612.

Bates, L.S., Waldren, R.P., Teare, I.D. 1973. Rapid determination of free proline for water stress studies. *Plant Soil.* 39: 205-207.

Chapman, D.H., Parker, E.R. 1961. Determination of NPK Methods of Analysis for Soil, Plant and Waters. Pub. Div. Agri. Univ. of California, USA, 150-179.

Dinar, A., Hassan, R., Mendelsohn, R., et al 2008. 2008 book reviews. *EarthScan.* 3: 20–28.

Goebel, M.O., Bachmann, J., Woche, S.K., et al 2005. Soil wettability, aggregate stability, and the decomposition of soil organic matter. *Geoderma.* 128: 80-93.

Golabi, M.H., Denney, M., Iyekar, C., et al 2004. Use of composted organic wastes as alternative to synthetic fertilizers for enhancing crop productivity and agricultural sustainability on the tropical island of guam. Paper read at proceedings of the 13th international soil conservation organization conference. Pp. 125-128.

Hargreaves, J., Adl, M., Warman, P., et al 2008. A review of the use of composted municipal solid waste in agriculture. *Agri. Ecosyst. Environ.* 123: 1-14.

Hodges, L., Daningsih, E., Brandle, J.R., et al 2006. Comparison of an antitranspirant spray, a polyacrylamide gel, and wind protection on early growth of muskmelon. *HortScience.* 41: 361–366.

Hosh, S., Pal, P., Ow, L.F., et al 2018. Effect of compost and hydroabsorbent polymer on tree growth and soil properties in a tropical urban environment. *Commun. Soil Sci. Plant Anal.* 49: 1229–1238.

Kim, M., Song, I., Kim, M., et al 2015. Effect of polyacrylamide application on water and nutrient movements in soils. *J. Agric. Chem. Environ.* 4: 76.

Kotir, J.H. 2011. Climate change and variability in sub-saharan africa: a review of current and future trends and impacts on agriculture and food security. *Env. Dev. Sustain.* 3: 587–605.

Latrach, L., Farissi, M., Mouradi, M., et al 2014. Growth and nodulation of alfalfa-rhizobia symbiosis under salinity: electrolyte leakage, stomatal conductance, and chlorophyll fluorescence. *Turkish J. Agric. For.* 38: 320-326.

Lee, S.S., Gantzer, C.J., Thompson, A.L., et al 2008. Using high resolution computed tomography analysis to characterize soil surface seals. *Soil Sci. Soc. J.* 72: 1478–1485.

Liang, X., Feng, R.Y., Meng, J.J., et al 2009. Effects of soil conditioners to soil water storage capacity. *J. Shanxi Agric. Sci.* 4: 53-55.

Lobell, D.B., Field, C.B. 2007. Global scale climate-crop yield relationships and the impacts of recent warming. *Environ. Res. Lett.* 2: 11–23.

Narasimhan, B., Srinivasan, R. 2005. Development and evaluation of soil moisture deficit index (SMDI) and evapotranspiration deficit index (ETDI) for agricultural drought monitoring. *Agric. For. Meteorol.* 133: 69–88.

Odegard, I.Y.R., Voet, E. 2014. The future of food - scenarios and the effect on natural resource use in agriculture in 2050. *Ecol. Econ.* 97: 51–59.

Olsen, S.R., Cole, C.V., Watanabe, F.S., et al 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular No. 939, USDA. US Government Printing Office, Washington, DC, USA.

Pennington, J.A.T., Stumbo, P.J., Murphy, S.P., et al 2007. Food composition data: the foundation of dietetic practice and research. *J. Am. Diet. Assoc.* 107: 2105–13.

Res, C., Trenberth, K.E. 2011. Changes in precipitation with climate change. *Clim. Res.* 47: 123–138.

Rollins, J.A., Habte, E., Templer, S.E., et al 2013. Leaf proteome alterations in the context of physiological and morphological responses to drought and heat stress in barley (Hordeum vulgare L.). *J. Exp. Bot.* 64: 3201–3212.

Seo, N., Mendelsohn, R., Dinar, A., et al 2008. A Ricardian analysis of the distribution of climate change impacts on agriculture across agro-ecological zones in Africa. *Environ. Resour. Econ.* 43: 313–332.

Sharma, S.R., Singh, P.K., Chable, V., et al 2005. A review of hybrid cauliflower development. *J. New Seeds.* 6: 151-156.

Steel, R.G.D., Torrie, J.H., Dicky, D.A., et al 1997. Principles and procedures of statistics, a biometrical approach. 3rd Edition, McGraw Hill, Inc. Book Co., New York, 352-358.

Thornton, P.K., Jones, P.G., Owiyo, T., et al 2008. Climate change and poverty in Africa: mapping hotspots of vulnerability. *Afri. J. Agric. Resour. Econ.* 2: 24–44.

Usman, K., Khan, S., Ghulam, S., et al 2012. Sewage sludge: an important biological resource for sustainable agriculture and its environmental implications. *Am. J. Plant Sci.* 3: 1708-1721.

Vadez, V., Kholova, J., Choudhary, S., et al 2011. Responses to increased moisture stress and extremes: whole plant response to drought under climate change. *Env. Dev. Sustain.* 28: 717–724.

Venkateswarlu, B., Shanker, A.K. 2009. Climate change and agriculture: adaptation and mitigation strategies. *Indian J. Agron.* 54: 226-230.

Walkley, A. 1947. A critical examination of a rapid method for determining organic carbon in soils-effect of variations in digestion conditions and of inorganic soil constituents. *Soil Sci.* 63: 251-264.

Wei, X., Yuan, X., Li, Y. Wang, Y. 2011. Research on the water-saving and yield-increasing effect of polyacrylamide. *Procedia Environ. Sci.* 11: 573–580.

Wu, H., Wu, X., Li, Z., et al 2012. Physiological evaluation of drought stress tolerance and recovery in cauliflower (*Brassica oleracea* L.) seedlings treated with methyl jasmonate and coronatine. *J. Plant Growth Regul.* 31: 113-123.

Yadav, S.S., McNeil, D.L., Redden, R. et al 2010. Climate change and management of cool season grain legume crops. *J. Plant Nutr.* 10: 50-61.

Yamasaki, S. Dillenburg, L. 1999. Measurements of leaf relative water content in *Araucaria angustifolia. Rev. Bras. Fisiol. Veg.* 11: 69–75.

Yamato, M., Okimori, Y., Wibowo, I.F., et al 2006. Effects of the application of charred bark of *Acacia mangium* on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. *Soil Sci. Plant Nutr.* 52: 489–495.

https://doi.org/10.55627/agribiol.003.01.1208