Turkish Journal of Agriculture - Food Science and Technology, 12(6): 1080-1087, 2024
DOI: https://doi.org/10.24925/turjaf.v12i6.1080-1087.6739

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Amelioration of the Detrimental Effects of Water Deficit Stress on Lentil (*Lens culinaris* Medik) Through the Utilization of Poultry Litter-Based Compost

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ARTICLE INFO

Research Article

Received : 26.02.2024
Accepted : 17.05.2024

Keywords:
Lentil (*Lens culinaris* Medik)
Poultry manure
Water stress
Growth
Development, yield.

ABSTRACT

It is critical that Bangladesh faces water scarcity during the dry season, affecting lentil (*Lens culinaris* Medik.) yield and some yield components during seedling and flowering stages. Thus, a two-factorial pot experiments (The experiment comprises Factor A: three fertilization levels i.e. F_1 = Control [inorganic], F_2 = poultry litter-based compost [20 ton/ha], F_3 = poultry litter-based compost [30 ton/ha]; Factor B: two irrigation levels such as W_1 = 100% field capacity [FC] and W_2 = 70% FC) were designed at Hajee Mohammad Danesh Science and Technology University, Dinajpur, from November 2018 to April 2019. And it was investigated how the poultry litter-based composts affected the morpho-physiology, yield and yield components of the lentil (BARI Masur-4) variety under different irrigation stress levels. Obtained results revealed that the tallest plant (30.7 cm at 75 DAS) and maximum branch number per plant (14.1 at 65 DAS), leaf chlorophyll a (0.30 mg/g), highest RLWC (70.28%), lowest proline content (1.57 µ moles g^{-1} FW), maximum number of pods per plant (39.4 at 75 DAS) and total grain yield (3.62 kg/m^2) were recorded from compost F_3 (poultry litter-based compost 30 tons/ha) with W_1 (100% FC). Results also showed that the yield contributing attributes and yield of lentils were drastically reduced by water stress conditions with different rates of fertilization. In drought conditions (W_2 = 70% FC), F_3 (30 ton/ha poultry litter-based compost) fertilization produced the highest plant height (30.20 cm at 75 DAS), number of branches (11.5 at 65 DAS), stem dry weight (0.35 g), lowest proline (3.88 µ moles g^{-1} FW), highest pod number per plant (33.1), weight of 100-seed (2.36 g), total grain weight (2.77 kg/m^2), harvest index (58.84%) compared to other fertilizations (F_1 and F_2). In summary, F_3 (30 tons), a compost made from poultry litter, provides better soil conditions under drought conditions compared to F_1 and F_2 in the year of 2018-19 at the 0 and 20 tons/ha, respectively under the field conditions.

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Introduction

Lentil (*Lens culinaris* Medik.), which belongs to the Fabaceae family, is a significant pulse crop cultivated in Bangladesh due to its crucial role in food, feed, and cropping systems (Iqbal et al., 2006). Legumes, when included in cropping systems, improve soil fertility and crop yield through nitrogen fixation (Abd El-hady et al., 2022), biological nitrogen fixation (BNF) – symbiotic association with microorganisms like rhizobia (Kebede, 2021). Benefits of legumes include increased nutrient availability and uptake for subsequent crops (Sinclair and Vadez, 2012; Hauggaard-Nielsen et al., 2008), improvement of soil properties (Jena et al., 2022), breaking pests' cycles (Stagnari et al., 2017), and enhancement of soil microbial activity (Yang et al., 2020). After chickpeas (*Cicer arietinum* L.) and peas (*Pisum sativum* L.), lentil is the 3rd most important grain legume in the globe (Sehgal et al., 2021), and has acquired the first position among the pulse crops considering area (3,60,699 acres) and production (1,85,500 MT) in 2020-21 in Bangladesh (BBS, 2022) but its production lower than the neighboring countries (Reddy et al., 2022). Additionally, according to WHO/FAO, the per capita requirement of pulse should be 45 g, although it is only about 17 g in Bangladesh which is very low and attributed to lower production of pulse crops (Anonymous, 2022). The reasons behind low production are minimum use of high-yielding variety and lack of proper cultivation management in different abiotic stresses. Water scarcity is identified as a major factor among the different abiotic stresses that hinder legume production, especially lentil (Fouad et al., 2011). Agricultural drought occurs when there is inadequate soil moisture in the root region due to inadequate precipitation throughout the growing season (Kamruzzaman et al., 2019; Wu, 2014; Khatun et al., 2021). Drought conditions cut down plant growth by modifying several physio-biochemical processes, e.g. photosynthesis, transpiration, respiration, translocation, imbalanced ion uptake, and nutrient metabolism (Amin and Baque, 2020). Moisture deficit-induced water stress may lead to significant production decreases, particularly in crops during critical stages of growth. Water deficiency impacts almost all physical and functional characteristics associated with development and may reduce crop output by up to 50% (Wang et al., 2003; Zubaer et al., 2007 Kabbadj et al., 2017). Oweis et al. (2004) also found that drought stress decreased lentil production by 54%. Lentil, often cultivated as a rainfed crop, sometimes confronts terminal moisture stress in dry areas, which causes premature maturity and reduced yield. The lentil yield in Iran is below the global average due to cultivation after the rainy season with low humidity (Lashkari and Bannayan, 2013). The initial phase of the flowering stage is extremely sensitive to water scarcity, which has a significant adverse effect on plant growth (Istanbulluoglu et al., 2009), while the maximum yield and its components can be obtained through full irrigation. However, maximum yield levels are typically attained when irrigation is sufficient during the flowering and fruit formation stages (Blum, 2005; Marković et al., 2017). In recent decades, organic compost (OC) implementation has increasingly been used to improve the condition of the soil where it is subjected to drought (Ozenc, 2008; Aryafar et al., 2021). Similarly, several studies showed that organic compost not only boosts soil nutrient availability but also improves soil quality (Chowdhury et al., 2020a). Organic compost is characterized by its high porosity, excellent ventilation, effective drainage, and significant water retention capacity, as well as a high cation exchange capacity (Rivier et al., 2022; Erhart and Hartl, 2010). Of all animal manure, poultry droppings have the highest nutritional levels. It includes macro-nutrients: N (4.55—5.46%), P (2.46—2.82%), K (2.02—2.32%), Ca (4.52—8.15%), and Mg (0.52—0.73%); and significant amounts of micro-nutrients (Cu, Mn, Fe, and Zn, etc) (Nagpal et al., 2022). Adding poultry manure to the soil enhances soil structure, nutrient preservation, aeration, soil moisture retention at field capacity, and easily water permeability more than chemical fertilizers (Farhad et al., 2009, Chowdhury et al., 2013). Several researchers described that organic compost such as poultry litter-based compost has a positive effect on drought conditions on crop production (Chowdhury et. al., 2020b; Farhad et al., 2009). Applying compost boosted the antioxidant enzyme activities in crops cultivated under drought circumstances compared to the control plants (Tartoura, 2010). Yassen et al. (2006) discovered that incorporating mineral nitrogen with poultry manure as an organic fertilizer and irrigation at 60% water holding capacity, resulted in the maximum yield across two growing seasons. In this case, we need to come up with an input package that includes a source of nutrients that is technically sound and feasible, flexible financially, socially acceptable, and beneficial for the environment for growing lentils. Therefore, the current experiment was undertaken to assess the influence of poultry liter-based compost on lentil production to subside water deficiency stress.

Materials and Methods

From November 2018 to April 2019, the investigation was performed at the Crop Physiology and Ecology (CPE) research farm at Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh, and the experimental site is situated at 25°39' N Latitude and 88°41' E Longitude, which is 37.58 m ASL.

Physico-Chemical Features of Soil

The soil of the experimental site, located in the Old Himalayan Piedmont Plain (AEZ-1), is characterized as non-calcareous brown floodplain soil of the Ranisankail series, situated above flood level on high land. It is a sandy loam with bulk density ranging from 0.86—1.07 g cm^{-3}. Chemically, the soil is moderately acidic (pH 5.40—5.50), with low organic carbon (0.70%) and organic matter (1.29%), low CEC (5.60 meq/100g), very low total N (0.06%), medium available P (46.75 ppm), and medium-low exchangeable K (0.18 meq/100g).

Experimental Design and Treatments

A two-factorial complete randomized design (CRD) experiment was adjusted to three replicates. Factor –A (Fertilization**):** F_1 = Control (Inorganic), F_2 = 20 ton/ha compost (poultry litter-based compost) and F_3 = 30 ton/ha compost (poultry litter-based compost). Factor –B (Irrigation levels): W_1 = 100% FC and W_2 = 70% FC. Irrigation: Pots were irrigated with 3.5 liters and 2.5 liters of water three times— 25 days, 40 days, and 55 days after planting— for a total of 100% and 70% field capacity (FC), respectively. Rainout covers were used to protect the crop from rain. Pot preparation: Pots were placed in the Research Field of CPE, HSTU, Dinajpur, with soil from a depth of 15 cm of usable land. After sun dried for a week, 15 kg soil was taken into each pot. Then N, P, K and other fertilizers were calculated based on soil amount, and organic composts (N-1.6%, P-1.21%, and K-0.35%) were applied according to treatments. Lentil (BARI Masur-4) seeds were sown and covered with loose soil. Finally, slight irrigation was given for uniform germination.

Data Collection and Statistical Analysis

All obtained data were subjected to an ANOVA statistical software test when plants were measured at 45, 55, 65, and 75 DAS, and the mean was calculated. Stem and root samples were separated and oven-dried at 70°C for 48 hours, and electric balance was used for dry weight (Bruns and Croy, 1985). The following formulas were used to find the chlorophyll-a, b, and total chlorophyll of a fresh leaf defined by Witham et al. (1986)

$$\text{Chl-a (mg/g)} = [12.7\ (D_{663})\ -2.69\ (D_{645})] \times V/1000\ W$$

$$\text{Chl-b (mg/g)} = [22.9\ (D_{645})\ -4.68\ (D_{663})] \times V/1000\ W$$

$$\text{Total Chl (mg/g)} = [20.21\ (D_{645})\ -8.02\ (D_{663})] \times V/1000\ W$$

Here,

D_{645} and D_{663} = Spectrophotometer reading at 645 nm Maintain the alignment 663 nm

V = 25 ml of 80% acetone

W = 0.25g fresh leaf

The proline (P) content of the youngest fully expanded leaf at 55 days after sowing of a lentil variety (BARI Masur-4) was grown in two water regimes (well water and water stress). The proline content was found from the standard curve and then computed based on fresh weight using the following formula according to Bates et al. (1973). The data were statistically analysed using the statistical software package (Statistix 10 software). The significant difference among the treatment means was estimated by the Tukey HSD test at a 5% level of significance (Gomez and Gomez, 1984).

$$P=\frac{\{(\mu g\ \text{proline}\ mL^{-1} \times ml\ \text{toluene})/115.5\mu g/\ \mu moles\}}{g\ \text{sample}\ /\ 5}$$

P: Proline (μ moles g^{-1} FW)

The relative leaf water content was estimated using the formula of Barrs and Weatherley (1962):

$$\text{RLWC}\ (\%)=\frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}}\times 100$$

The biological yield and harvest index (HI) were calculated with the following formula: (Donald and Hamblin, 1976; Sinha et al., 1982)

Biological yield = Grain yield + Straw yield

$$\text{Harvest index}\ (\%)=\frac{\text{Economic yield (Grain yield)}}{\text{Biological yield}}\times 100$$

Results

Effect of Poultry-Litter-Based Compost

The plant height of lentil variety (BARI Masur-4) varied significantly when poultry litter-based composts were applied (Table 1) except for days 45 and 55 after sowing (DAS). The tallest plant heights (20.05 cm, 23.75 cm, 28.65 cm, and 30.45 cm) were produced by F_3 (30 ton/ha poultry litter-based compost), while the shortest plant heights (18.30 cm, 21.65 cm, 26.65 cm, and 28.45 cm) were recorded from F_1 (control) treatment at 45, 55, 65, and 75 days after sowing (DAS), respectively. Regarding branch number (Table 1), at 45, 55, and 65 DAS, F_3 (30 ton/ha poultry litter-based compost) had the most significant branch numbers (3.85, 8.95 and 12.8, respectively), whereas F_1 (Control) had the least branch numbers (3.2, 5.9 and 8.65, respectively). In addition, the dry matter accumulation at the stem and root was increased by 221.42% and 180% for F_3 (30 ton/ha poultry litter-based compost) compared to the control treatment (Table 1). Different composts based on poultry litter substantially impacted the amount of chlorophyll in the leaves (Table 2). The findings showed that, except for 50 DAS, F_1 (inorganic) typically had lower chlorophyll content than F_2 (20 tons/ha) and F_3 (30 tons/ha) of organic compost. Chlorophyll a, b, and total chlorophyll concentrations were greater in F_2 and F_3 compared to F_1 at 40 and 60 DAS. As the quantity of compost based on chicken litter increased, also increased the RLWC (Table 2). Compared to the F_1 treatment, the RLWC increased by 14.37% after the F_3 (30-ton/ha poultry litter-based compost) treatment. On the other hand, proline concentration varied considerably as a result of composts derived from poultry (Table 2). The F_3 (30 ton/ha poultry litter-based compost) treatment had the lowest proline (2.72 μ moles g-1 FW), 65.79% less than the F_1 treatment. According to Table 3, at 55, 65, and 75 days after planting, respectively, the highest pod numbers (12.38, 24.95, and 36.25) were discovered in F_3 (30 ton/ha poultry litter-based compost), whereas the shortest pod numbers were in F_1. Table 3 showed that the F_3 (30 ton/ha poultry litter-based compost) recorded the maximum 100-seed weight (2.645g), whereas the F_1 (inorganic) recorded the minimum 100-seed weight (1.93g). The results also demonstrated that various fertilization treatments enhanced grain production (kg/m^2) (Table 3). F_3 (poultry litter-based compost 30 tons/ha) had the most outstanding grain yield (3.195 kg/m^2), whereas F_1 (control) exhibited the lowest grain yield (1.715 kg/m^2). Poultry litter-based composts showed a significant effect on the yield-contributing features (Table 3). As shown in the table, F_3 (30 ton/ha poultry litter-based compost) produced the highest biological yield and harvest index (5.21 kg/m^2 and 60.67%, respectively). However, F_1 (control) reported the least biological yield and harvest index (3.01 kg/m^2 and 53.15%, respectively).

Effect of Irrigation Levels

Varying watering levels had a notable impact on both the height of the plants and the branch number (Table 1). It was found that the tallest plants (20.50 cm, 23.46 cm, 28.56 cm and 30.26 cm at 45, 55, 65, and 75 DAS respectively) were recorded from W_1 irrigation level (100% FC) but the shortest plants (18.80 cm, 22.35 cm, 27.16 cm and 29.16 cm at 45.0, 55.0, 65.0, and 75 DAS respectively) were recorded from W_2 irrigation level (70% FC). Treatment W_1 showed the highest branch numbers (3.8, 8.33 and 12.1) while the lowest branch numbers (3.36, 6.74 and 9.6) were observed at 45, 55, and 65 DAS respectively from W_2 (70% FC). Additionally, Table 2 also presented that W_1 (100% FC) had the most chlorophyll concentration, which decreases with decreasing water levels. The leaf water content was 10.14% lower in comparison to the W_1 treatment. W_2, at 70% FC, exhibited the greatest proline concentration of 5.95 μ moles g^{-1} FW, which was 48.75% higher than at 100% FC. The yield-contributing factors also varied significantly in terms of water levels, as shown in Table 3. The highest pod numbers (12.6, 22.2 and 33.2) were also observed in well water (100% FC) at 55, 65, and 75 days after sowing, while the shortest pod numbers were noted during water deficiency stress (70% FC). The various irrigation levels shown in (Table 3) had a substantial impact on the production of lentil yield. W_1 (100% FC) (well water condition) had the greatest 100-grain weight, biological yield, and harvest index (2.50 g, 4.57 kg/m^2, and 58.88%, respectively), whereas W_2 (70% FC) (water shortage stress) had the lowest values (2.12 g, 3.74 kg/m^2 and 56.26%, respectively).

Table 1. Effect of fertilization and watering level on morphological traits of (BARI Masur-4) at different days after sowing (DAS)

Treatments	Plant height (cm)				Number of branches plant^{-1}			Stem		Root	
	45	55	65	75	45	55	65	DW	COC	DW	COC
Fertilizers											
F_1	18.30c	21.65c	26.65c	28.45c	3.2c	5.9c	8.65c	0.14c		0.010c	
F_2	20.60a	23.33b	28.30b	30.25b	3.7b	7.76b	11.1b	0.39b	+178.57	0.0225b	+125.0
F_3	20.05b	23.75a	28.65a	30.45a	3.85a	8.95a	12.8a	0.45a	+221.42	0.028a	+180.0
LS	**	**	**	**	**	**	**	**		**	
Water Regimes											
W_1	20.50a	23.46a	28.56a	30.26a	3.8a	8.33a	12.1a	0.41a		0.025a	
W_2	18.80b	22.35b	27.16b	29.16b	3.36b	6.74b	9.6b	0.24b	-41.46	0.015b	-40.0
LS	**	**	**	**	**	**	**	**		**	
(Fertilizers × Water Regimes)											
$F_1 \times W_1$	19.30c	21.90e	27.40e	29.50e	3.2e	6.6e	9.7d	0.19e		0.014cd	
$F_1 \times W_2$	17.30e	21.40f	25.90f	27.40f	3.2e	5.2f	7.6e	0.10f	-47.37	0.006d	-57.14
$F_2 \times W_1$	20.70b	24.10b	28.90b	30.60b	4.0b	8.5b	12.5b	0.49b		0.028b	
$F_2 \times W_2$	20.50b	22.56d	27.70d	29.90d	3.4d	7.03d	9.7d	0.29d	-28.57	0.017c	-39.29
$F_3 \times W_1$	21.50a	24.40a	29.40a	30.70a	4.2a	9.9a	14.1a	0.55a		0.033a	
$F_3 \times W_2$	18.60d	23.10c	27.90c	30.20c	3.5c	8.0c	11.5c	0.35c	-36.37	0.023bc	-30.30
CV (%)	1.29	0.53	0.08	0.10	0.38	0.16	0.10	3.15		4.10	
LS	**	**	**	**	**	**	**	**		**	

F_1 = Control (inorganic), F_2 = 20 ton/ha compost (poultry litter-based compost), F_3 = 30 ton/ha compost (poultry litter-based compost), W_1 = 100% field capacity, W_2 = 70% field capacity, CV= Co-efficient of variance, LS= Level of significance, ** indicates significant at 1% level of probability, * indicates significant at 5% level of probability; DW: Dry weight (g); COC: % change over control

Table 2. Effect of fertilization and watering level on chlorophyll content at different DAS, water status and proline accumulation of the (BARI Masur-4)

Treatment	Chlorophyll (mg/g) 40 DAS			Chlorophyll (mg/g) 50 DAS			Chlorophyll (mg/g) 60 DAS			Water status		Proline accumulation	
	Chl a	Chl b	Total Chl	Chl a	Chl b	Total Chl	Chl a	Chl b	Total Chl	RLW	COC	PR	COC
Fertilizer													
F_1	0.25b	1.05c	0.84ab	0.18a	0.81a	0.62a	0.14b	0.94c	0.75c	57.74c		7.93a	
F_2	0.27a	1.12a	0.86a	0.14b	0.61b	0.47b	0.18a	0.99b	0.795b	64.01b	+10.85	4.27b	-46.15
F_3	0.28a	1.09b	0.83b	0.14b	0.60b	0.46c	0.15b	1.05a	2.09a	66.04a	+14.37	2.72c	-65.79
LS	**	**	**	**	**	**	**	**	**	**		**	
Water regimes													
W_1	0.27a	1.12a	0.86a	0.17a	0.74a	0.57a	0.14b	1.0a	0.79b	65.94a		4.00b	
W_2	0.27a	1.05b	0.83b	0.14b	0.61b	0.46b	0.16a	0.99a	1.62a	59.25b	-10.14	5.95a	+48.75
LS	*	**	**	**	**	*	**	*	**	**		**	
(Fertilizer × Water regimes)													
$F_1 \times W_1$	0.24b	1.09c	0.83b	0.20a	0.87a	0.67a	0.13d	0.97c	0.77c	58.61e		7.37 b	
$F_1 \times W_2$	0.27ab	1.02d	0.86ab	0.17ab	0.76b	0.58b	0.15d	0.92d	0.73de	56.88f	-2.95	8.49 a	+15.19
$F_2 \times W_1$	0.28a	1.13ab	0.87a	0.14bc	0.67d	0.52c	0.17b	1.08b	0.87b	68.95b		3.07 e	
$F_2 \times W_2$	0.27ab	1.11bc	0.85ab	0.14bc	0.56e	0.43d	0.19a	0.91d	0.72e	59.08d	-14.31	5.48 c	+78.50
$F_3 \times W_1$	0.30a	1.15a	0.88a	0.17ab	0.70c	0.53c	0.14d	0.95c	0.75cd	70.28a		1.57 f	
$F_3 \times W_2$	0.27ab	1.03d	0.78c	0.12c	0.51f	0.39e	3.43a	1.14a	3.43a	61.81c	-12.05	3.88 d	+147.13
CV (%)	4.51	0.96	1.45	8.48	1.20	1.57	5.59	0.99	0.81	0.05		0.19	
LS	**	**	**	*	**	*	*	**	**	**		**	

F_1 = Control (inorganic), F_2 = 20 ton/ha compost (poultry litter-based compost), F_3 = 30 ton/ha compost (poultry litter-based compost), W_1 = 100% field capacity, W_2 = 70% field capacity, CV= Co-efficient of variance, LS= Level of significance, ** indicates significant at 1% level of probability, * indicates significant at 5% level of probability; RLW: Relative Leaf Water Content (%); COC: % change over control; PR: Proline (µ moles g^{-1} FW)

Interaction effect

Interaction between fertilization and different watering levels showed significant plant height at different DAS and were presented in (Table 1). The results showed that at 45, 55, 65, and 75 DAS, the tallest plant heights (21.50 cm, 24.40 cm, 29.40 cm, and 30.70 cm, respectively) were found in F_3W_1 (compost 30 ton/ha + 100% FC), which was considerably different from other treatments. On the other hand, the shortest plant heights (17.30 cm, 21.40 cm, 25.90 cm, and 27.40 cm, respectively) were found from F_1W_2 (inorganic + 70% FC). The interaction effect between the fertilization and water regimes (Table 1) in the highest branch numbers (4.2, 9.9, 14.1 at 45, 55.0, and 65 DAS) were found in F_3W_1 (30 ton/ha organic with 100% FC). At 45 DAS, the lowest number of branches (3.2) was recorded from both F_1W_2 and F_1W_1. At 55 and 65 DAS, the minimum branch number (5.2 and 7.6, respectively) was found at F_1W_2 (inorganic + 70% FC). The combined effect of fertilization and water regimes was significant on the stem and root dry weight per plant of lentils (Table 1). The maximum stem dry weight (0.55 g) was obtained from F_3W_1 (30 ton/ha poultry litter-based compost with 100% FC), and the minimal stem dry weight (0.10 g) was observed in F_1 (inorganic) under water stress conditions (70% FC). Due to water stress, a greater reduction in stem dry weight was obtained 47.37% in F_1 (inorganic) and 36.67% in F_3 (30 ton/ha poultry litter-based compost) compared to 28.57 % in F_2 (20 ton/ha poultry litter-based compost). Similarly, the highest root dry weight (0.033 g) was obtained from F_3W_1 (30 ton/ha poultry litter-based compost + 100% FC) while the minimal root dry weight (0.006 g) was observed in F_1 (inorganic) under water stress condition (70% FC). Because of water stress (70% FC), the reduction in root dry weight was obtained at 57.14% in F_1 (control) and 39.29% in F_2 (20 ton/ha poultry litter-based compost) compared to 30.30% in F_3 (30 ton/ha poultry litter-based compost). For the chlorophyll content (Table 2), F_1W_1 had less chlorophyll than F_1W_2 at all DAS except for 50 DAS. Chlorophyll levels were always higher in F_2W_1 than in F_2W_2. The chlorophyll levels in F_3W_2 at 60 DAS were very high, especially in chlorophyll a and total chlorophyll. The interaction of compost and watering levels also significantly influenced leaf water content (Table 2). F_3 (61.81%) showed a higher RLWC compared to F_2 (59.08%) under drought conditions (W_2). The results, displayed in Table 2, revealed that the inorganic fertilizer F_1W_2 (8.49 µ moles g^{-1} FW), and the organic compost F_2W_2 and F_3W_2 (8.49 and 5.48 µ moles g^{-1} FW respectively) minimized the effects of stress conditions compared to their control treatment F_2W_1 (3.07 µ moles g^{-1} FW) and F_3W_1 (1.57 µ moles g^{-1} FW) respectively. However, the change percentage over control was higher in organic compost (F_2 and F_3) than inorganic compost (F_1). In the case of yield contributing characters (Table 3), the highest pod numbers were also found in F_3W_1 at 55 DAS, F_1W_2, 65 DAS, and 75 DAS. Also, under W_2 (70% FC), F_3 (22.7 and 33.1) showed the highest value than F_2 (16.7 and 23.6) at 65 and 75 DAS, respectively. The interaction effect of poultry litter-based composts and various watering levels notably influenced the yield of lentils (Table 3). The utmost 100-grain weight (2.93 g) was noted for F_3W_1 (30 ton/ha poultry litter-based compost with 100% FC treatment) followed by F_2W_1 (20 ton/ha poultry litter-based compost with 100% FC) and F_1W_1 (Control with 100% FC). In the case of W_2, the same trend was also observed. The highest grain yield (3.62 kg/m^2) was recorded from F_3W_1 (30 ton/ha poultry litter-based compost with 100% FC treatment) followed by F_2W_1 (20 ton/ha poultry litter-based compost with 100% FC) and F_1W_1 (Control with 100% FC). The least grain yield (1.63 kg/m^2) was found for F_1W_2 (Control with 70% FC). But F_3W_2 and F_2W_2 treatments exhibited higher 100-grain yield than F_1W_2. The highest biological yield (5.48 kg/m^2) was recorded from F_3W_1 (30 ton/ha poultry litter-based compost with 100% FC) which was not statistically similar to F_2W_1 (20 ton/ha poultry litter-based compost with 100% FC) and F_1W_1 (Control with 100% FC). In contrast, the lowest biological yield (2.7 kg/m^2) was recorded from F_1W_2 (Control with 100% FC), which is also lower than F_2W_2 (3.5 kg/m^2) and F_1W_2 (4.95 kg/m^2). The results indicate that F_3 under stress conditions had increased the biological yield than other similar treatment combinations. The maximum harvest index (62.51%) was exhibited by F_3W_1 (30 ton/ha poultry litter-based compost with 100% FC) followed by F_2W_1 (20 ton/ha poultry litter-based compost with 70% FC) and F_3W_2 (Control with 100% FC) whereas F_1W_2 (Control with 70% FC) showed the lowest harvest index (51.43%).

Table 3. Effect of fertilization and watering level on yield contributing characters and yield of the (BARI Masur-4)

Treatments	Pods no/plant			Some Yield Components			
	55 DAS	65 DAS	75 DAS	100 seed weight (g)	Total grain weight (kg/m^2)	Biological yield (kg/m^2)	Harvest Index (%)
Fertilizer							
F_1	9.93c	14.5c	22.15c	1.93c	1.71c	3.01c	53.15c
F_2	11.73b	20.5b	30.5b	2.36b	2.54b	4.24b	58.88b
F_3	12.38a	24.95a	36.25a	2.64a	3.19a	5.21a	60.67a
LS	**	**	**	**	**	**	**
Water Regimes							
W_1	12.6a	22.2a	33.2a	2.50a	2.87a	4.57a	58.88a
W_2	10.10b	17.76b	26.88b	2.12b	2.09b	3.74b	56.26b
LS	**	**	**	**	**	**	**
(Fertilizer × Water Regimes)							
$F_1 \times W_1$	11.9c	15.1e	22.8e	2.07e	1.8e	3.24e	54.87e
$F_1 \times W_2$	7.97e	13.9f	21.50f	1.79f	1.63f	2.7f	51.43f
$F_2 \times W_1$	12.3b	24.3b	37.4b	2.50b	3.19b	4.99b	59.26b
$F_2 \times W_2$	11.17d	16.7d	23.6d	2.22d	1.89d	3.5d	58.51d
$F_3 \times W_1$	13.6a	27.2a	39.4a	2.93a	3.62a	5.48a	62.51a
$F_3 \times W_2$	11.17d	22.7c	33.1c	2.36c	2.77c	4.95c	58.84c
CV (%)	0.12	0.11	0.80	0.48	0.33	0.30	0.02
LS	**	**	**	**	**	**	**

Here, F_1 = Control (inorganic), F_2 = 20 ton/ha compost (poultry litter-based compost), F_3 = 30 ton/ha compost (poultry litter-based compost), W_1 = 100% field capacity, W_2 = 70% field capacity, CV= Co-efficient of variance, LS= Level of significance, ** indicates significant at 1% level of probability, * indicates significant at 5% level of probability

Discussion

Poultry litter compost is a powerful organic fertilizer comprising high levels of nitrogen (N), phosphorous (P), potassium (K), and other essential elements that are easily absorbed by plants, allowing for increased production of crops compared to other organic matter sources (Adeyemo et al., 2019; Mohamed et al. 2010). Poultry compost enhances the growth, and development of lentils (Aktar et al., 2019), green gram (*Vigna radiata* L.) (Yadav et al., 2007), and mung bean [*Vigna radiata* (L.) Wilczek] (Choudhary et al., 2013). Various research has established that water stress causes a decrease in growth, as seen by changes in plant growth parameters such as height, number of branches, and dry matter (Zubaer et al., 2007, Boutraa et al., 2010; Talukdar, 2013). Poultry manure can overcome the harmful effect on morphological traits induced by different abiotic stress e.g., low moisture level (El-Samnoudi et al., 2019), salinity (Oustani et al., 2015; Rasool et al., 2023)

The maximum field capacity creates a suitable environment for proper plant development and water stress reduces branch number. El-Samnoudi et al. (2019) also found similar results. Water deficits in lentils reduce germination, leaf area, shoot and root growth, membrane stability, relative water content, photosynthesis, and biomass output. (Zeroual et al., 2022). Low moisture levels caused a substantial reduction in dry matter in different parts of the crop (Mishra et al., 2018). However, manure-treated plants with low moisture levels possess higher weight than only stressed plants (Lin, 2018). Chlorophyll is a crucial pigment in plants responsible for photosynthesis, the process by which plants transform sunlight into energy. dos Santos et al., (2022) stated that drought conditions can stress plants and affect various physiological processes, including photosynthesis. Al-Gaadi et al., (2019) found that among the tested crops, the content of chlorophyll was better in areas where poultry manure was treated. With limited water availability, cells in the plant undergo dehydration. This can lead to a decrease in turgor pressure, causing cells to lose their normal shape and structure. The loss of water from plant cells contributes to an overall reduction in the relative water content of the leaves. However, compost can enhance water holding capacity in the soil and plants can uptake water easily (Pirzad et al., 2011; Diacono et al., 2011; Farhad et al., 2011).

ROS (Reactive oxygen species) are extremely sensitive chemicals that may harm cellular constituents. Drought stress can generate the production of ROS in plant cells (Cruz, 2008). Proline has been shown to act as a scavenger of ROS, helping to protect cells from oxidative stress associated with drought (Lee et al., 2019; Cruz, 2008). A possible mechanism that contributes to the plant’s capability to protect itself against oxidative damage is the accumulation of proline (Zulfiqar and Ashraf, 2023). Various organic amendments such as PM can be used for the amendment of stressful soils (Baddour et al., 2017). Likewise, in general, proline levels are greater in stress-tolerant types compared to stress-sensitive ones (Shafi et al., 2019; Dar et al., 2016). It was revealed that drought stress during critical stages (flowering and pod setting) of lentils can lead to a reduction in the number of pods formed (Shrestha et al., 2006). Water scarcity may limit the plant's ability to allocate resources for reproductive structures, resulting in fewer pods being initiated (Sarkar et al., 2021). Ahmed et al., (2022) stated that Organic manure, especially poultry litter compost, enhances soil water retention, creating a more favourable environment for plant growth. The fortification of biochar with poultry manure, as stated by Shah et al., (2023), can enhance soil productivity. This is because it helps to preserve the soil fertility and contributes to the improvement of crop yield. The positive effect of poultry compost on the yield of crops was also discovered by Shah et al., (2023) and Ahmed et al., (2022).

Conclusion

The current study revealed that the application of F_3 (30 ton/ha poultry litter-based compost) gave better growth and yield of lentil variety (BARI Masur-4) at optimum irrigation (100% FC) than F_1 (inorganic fertilizer). Watering level in soil has also a direct correlation with the growth and yield of lentils. The production of lentils declines with reducing water level but the detrimental effects of it subsided by the application of more poultry litter bases compost. Therefore, it has been suggested that F_3 (30 ton/ha, poultry litter-based compost) offered better soil conditions under drought conditions compared to F_1 (inorganic fertilizer) and F_2 (20 ton/ha poultry litter-based compost).

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