Journal of Environmental and Agricultural Studies
ISSN: 2710-1401
DOI: 10.32996/jeas
Journal Homepage: www.al-kindipublisher.com/index.php/jeas

JEAS
AL-KINDI CENTER FOR RESEARCH AND DEVELOPMENT

| RESEARCH ARTICLE

Assessing the effects of Different Biofertilizer Levels on Dry-weight of Wheat and Barley Cultivars at Maturity Stage

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| ABSTRACT
The current study was conducted to investigate the effect of biofertilizers on some physiological and agronomical characteristics of different varieties of wheat and barley at the physiological maturity stage in 2021 at the new campus of Gorgan University of Agricultural Sciences and Natural Resources. The experiment was a Completely Randomized Factorial Design with two factors; the first factor was the inoculation of biofertilizer at three levels (Barvar-2, Actinomycetes, Barvar-2 + Actinomycetes), and the second factor was wheat and barley at 14 levels (eight varieties of wheat: Marwarid, Gonbad, Karim, Ihsan, Darya, N-91-8, N-91-9, and N-91-17 and six varieties of barley: Mahor, Torkman, Sahra, Boomy, Yusuf, and Lukht) all with three replications. Results indicated that the effect of genotype on all the traits considered in this study (leaf dry weight, stem, root, shoot, and total) was significant at a 1% level of confidence and that barley (Boomy and Sahra cultivars) had higher amounts of dry weight. On the other hand, biofertilizer did not reveal a significant effect on the traits; however, the interaction of genotype and biofertilizer indicated a significant effect on the dry weight of roots, and the highest amount was found in Marwarid genotype and actinomycetes experiment.

| KEYWORDS

Actinomycetes, Barvar-2, Biofertilizer, Plant organs, Variety, Wheat and barley

| ARTICLE INFORMATION

ACCEPTED: 26 November 2022 **PUBLISHED:** 03 December 2022 **DOI:** 10.32996/jeas.2022.3.3.8

1. Introduction
Information on the concentration and accumulation of nutrients and production of dry weight and the way they are distributed among plant organs in different species show the genetic diversity associated with these traits. Such traits help optimize the nutritional mineral of crops (Abidi *et al.,* 2018). Various measures have been taken to increase the production of agricultural products, including the use of chemical fertilizers and pesticides. In addition to higher costs, chemicals cause critical harm to the environment. Biofertilizers consist of useful bacteria and fungi, each of which has a specific purpose, such as nitrogen fixation and the release of potassium, phosphorus, and Iron ions from their insoluble compounds (Medina & Rosario Azcón, 2010). Biofertilizers or biological fertilizers are inoculated microbially to provide one or several nutritional requirements of plants. These substances are used as inoculated with seeds, soil, or organic fertilizers (Eidizadeh *et al.*, 2011).

The barvar-2 phosphate biofertilizer contains two types of phosphate-solubilizing bacteria; Bacillus lentus (strain p5), which releases phosphate from the mineral compound by producing organic acid, and Pseudomonas putida (strain P13), which produces phosphatase enzyme (Zaredost *et al.*, 2014). (Madani *et al.,* 2004) investigated the effect of barvar-2 phosphate biofertilizer on yield and other characteristics of sugar beet in the Karaj and Arak regions and observed that not only the quantity but the quality of the crop increased significantly. Further, actinomycetes are also known as phosphate-solubilizing microorganisms (Jung *et al.*, 2002).

Unlike other microbial groups, Actinomycetes create complex physiological and morphological adaptations in the soil, so, less affected by adverse environmental factors. Not only do they contain a dominant group of soil microflora, but produce spores under stressful conditions to survive. Additionally, they can significantly occupy plants' roots and improve growth (Sadeghi *et al.*, 2012). (*Gahoonia & Nielsen, 1996*) illustrated that varieties of winter wheat and spring barley varieties were more efficient in utilizing phosphorus than winter barley varieties. They attributed the genotypes' diversity in the efficient utilization of phosphorus to the differences in their root hairs and secretions.

(Horst *et al.*, 1993) considered the superiority of a new wheat variety in comparison to a Boomy cultivar in the efficient utilization of phosphorus, mobilization of phosphorus, and root morphology. Ozturk *et al.* (2005) studied different types of cereals in two types of soil with low and high amounts of phosphorus and concluded that the total amount of phosphorus uptake could be used as a criterion for identifying efficient species. Similarly, there was considerable variation in spring wheat genotypes in terms of phosphorus uptake and its efficient utilization (Gill *et al.*, 2004).

Subsequently, this study was conducted to investigate the performance of changes in dry weight and genotype of wheat and barley at the stage of maturation using different inoculation treatments of biofertilizers.

2. Methodology

The current experiment was conducted at the new campus of Gorgan University of Agricultural Sciences and Natural Resources in 2020 to investigate the effect of biofertilizers on some agronomical characteristics of wheat and barley. The soil sample was tested to determine its physical and chemical properties.

The experimental design was a completely randomized factorial design with three replications and two factorials. The two factors were inoculation with biofertilizer at three levels (Barvar-2, Actinomycetes, Barvar-2 + Actinomycetes) and wheat and barley cultivars at 14 levels (eight varieties of wheat: Marwarid, Gonbad, Karim, Ihsan, Darya, N-91-8, N-91-9, and N-91-17 and six varieties of barley: Mahor, Torkman, Sahra, Boomy, Yusuf, and Lukht) all with three replications. The soil required for the experiment was procured from the campus of Gorgan University of Agricultural Sciences and Natural Resources, and 12 kg of dry soil was measured for each pot. Fertilizers to be applied (inoculated) were calculated based on the dry soil weight of the pot to the dry soil weight of one-hectare land at a depth equal to the pot.

Nitrogen-based fertilizer was urea at the rate of 180 kg/ha and applied in three stages planting, tillering, and the first node or beginning of stem elongation (one-third of the total at each stage). Moreover, potassium fertilizer was potassium chloride at the rate of 120 kg/ha, and phosphorus fertilizer was procured from triple superphosphate at the rate of 20 kg/ha, which was applied to the soil at the time of planting.

After inoculation of seeds with bacteria, wheat and barley were planted in pots of 25 cm in diameter and 18 cm in height. Initially, 30 seeds were planted in each pot, but finally, excess plants were removed to reach the density of 10 plants per pot (360 plants per square meter, based on the desired plant density in field conditions. Later at the stage of physiological maturity, green and yellow leaves were detached from the stem, and the organs were distinguished into roots, stem (including stem, leaf sheets at the stage of physiological maturity, spike without seed), green leaf (leaves with more than 50% greenness), yellow leaf (leaves with more than 50% yellowish), and seeds. Subsequently, samples were kept in paper bags and placed in the oven at 70 °C for 48 hours. Later on, the dried weight was measured on the scale with an accuracy of 0.001 g.

Finally, data were analyzed by SAS 9.4 statistical software, and the means were compared using the least significant difference (LSD) test at 5% level of confidence.

3. Results

3.1 Physical and chemical properties of tested soil

The soil sample was tested to determine its physical and chemical properties. Based on the results, the organic carbon of the soil was 1.13%, electrical conductivity (0.6 dS / m), acidity was 7.9, total nitrogen was 0.11, and percentages of clay, silt, neutral weight, and sand were 30, 64, 11.5 and 6% respectively. Correspondingly, the soil texture was silt-clay-loam (Si-C-L) type.

3.2 Dry weight of leaves, stems, seeds, aerial parts, and the whole plant

The results of the analysis of variance revealed that only the effect of genotypes on leaf dry weight, stem, seed, shoot, and aerial parts of the plant was significant at a 1% level of confidence, but the effect of Barvar-2 biofertilizer and actinomycetes were not significant on the mentioned traits (Table 1).

Table 1: Genotype, biofertilizer and their interaction effects on the dry weight of different cultivars of wheat and barley

		Mean squares					
Source of Variation	Degrees of freedom	leaf dry-weight	stem dry-weight	grain dry-weight	Shoot dry-weight	Total dry-weight	Root dry-weight
Genotype	13	0.1524^{**}	0.4936^{**}	1.2533^{**}	2.6486^{**}	2.6672^{**}	0.0244^{**}
Biofertilizer	2	0.0054^{ns}	0.0315^{ns}	0.0660^{ns}	0.2348^{ns}	0.2467^{ns}	0.0004^{ns}
Genotype Biofertilizer	26	0.0072^{ns}	0.1117^{ns}	0.1690^{ns}	0.5944^{ns}	0.6152^{ns}	0.0109^{ns}
Error	84	0.0092	0.1076	0.1229	0.5039	0.5171	0.0039
Coefficient of Variation (%)		19.90	15.96	19.08	16.23	15.26	18.63

** Significant at 1% level of confidence, ^{ns} Not significant

The comparison of the means revealed that the highest amounts of the leaf and stem dry weights were related to the Boomy cultivar, with an average of 0.712 gr and 2.456 gr per plant, respectively. The highest grain dry weight was related to the Yusuf cultivar, with 2.366 gr per plant; shoot parts along with the whole plant dry weight were higher in the Sahra cultivar, with 5.154 gr and 5.532 gr per plant, respectively. The lowest amount for the mentioned traits was concerned with Darya, Gonbad, Karimi, Marwarid, and N-91-9 genotypes with 0.348, 1.242, 1.861, 3.478, and 3.772 gr per plant, respectively (Table 2).

Table 2: Mean comparison of the effect of genotype on the production and distribution of dry weight under different biofertilizers

Crop's genotype	Leaf dry-weight	Stem dry-weight	grain dry-weight	Shoot dry-weight	Total dry-weight
	(gm/plant)				
Boomy	0.712^{a}	2.456^{a}	2.012^{bcd}	5.181^{a}	5.453^{ab}
Darya	0.348^{d}	1.861^{d}	1.242^{g}	3.478^{g}	3.772^{f}
Ehsan	0.438^{d}	2.108^{cd}	1.509^{fg}	4.055^{ef}	4.378^{cde}
Gonbad	0.418^{cd}	2.259^{abc}	1.550^{fg}	4.277^{fg}	4.568^{ef}
Karimi	0.375^{cd}	1.932^{d}	1.444^{fg}	3.723^{efg}	4.065^{def}
Lukht	0.425^{c}	1.517^{cd}	2.025^{bcd}	3.956^{d-g}	4.272^{bcd}
Mahor	0.440^{c}	1.980^{cd}	2.147^{abc}	4.567^{a-d}	4.850^{bcd}
Marwarid	0.380^{cd}	1.996^{cd}	1.476^{fg}	3.852^{efg}	4.313^{def}
N-91-17	0.446^{c}	2.090^{cd}	1.896^{cde}	4.435^{b-e}	4.786^{bcd}
N-91-8	0.411^{cd}	2.406^{ab}	1.746^{def}	4.562^{a-d}	4.946^{a-d}
N-91-9	0.729^{cd}	$2.146b^{cd}$	1.657^{ef}	4.181^{c-f}	4.445^{def}
Sahra	0.727^{a}	2.061^{cd}	2.366^{a}	5.154^{a}	5.532^{a}

Torkman	0.655[ab]	1.904[d]	2.277[ab]	4.137[abd]	5.178[abc]
Yusof	0.577[b]	2.072[cd]	2.390[a]	5.039[ab]	5.401[ab]
LSD	0.090	0.308	0.329	0.665	0.674

Ozturk *et al.* (2005) observed considerable variation in varieties in terms of efficient phosphorus utilization in different turgidum and estivum species of wheat and stated that phosphorus intake was the most important factor determining the efficient utilization of phosphorus. They also employed the relative dry weight of the shoot parts as the phosphorus efficiency index and illustrated that in case of phosphorus insufficiency, total plant phosphorus and the shoot's dry weight could be used as reliable indices to evaluate the efficient utilization of the phosphorus.

3.3 Root dry weight

The analysis of variance on root dry weight indicated a significant effect of main genotype and dual interaction of (Barvar-2 + Actinomycete) biofertilizers at a 1% level of confidence, but the application biofertilizer alone had no significant effect on this trait (Table 1). Concerning to comparison of the mean indicated, it was revealed that the highest amount of root dry weight belonged to the Marwarid genotype and Actinomycete treatment with 0.511 gm per plant and the lowest to Boomy genotype and biofertilizer (Barvar-2 + Actinomycete) treatment with 0.249 gm per plant (Figure 1).

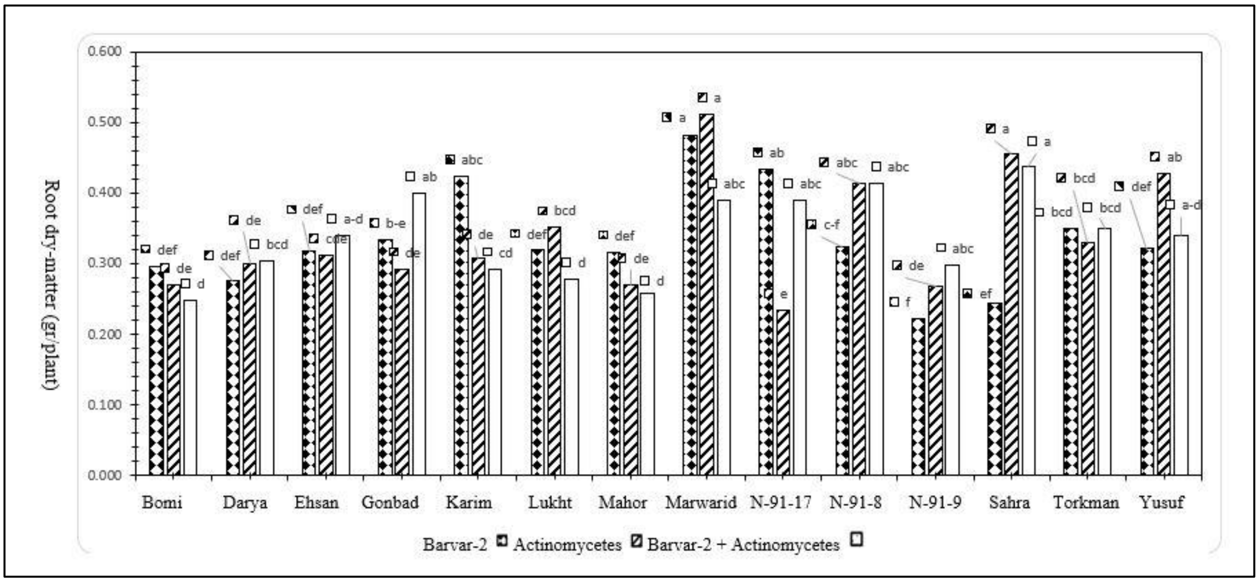

Figure 1: Results of comparing means related to the interaction of biofertilizers and genotypes on root dry-weight

Actinomycetes create complex physiological and morphological compatibility in the soil; therefore, they are less likely to be affected by antagonistic environmental factors compared to other microbial groups. Not only do such microorganisms form a dominant part of soil microflora, but they are also able to produce spores and survive under stressful conditions. On the other hand, they are able to occupy plant roots effectively and improve their growth (Sadeghi *et al.,* 2021).

There are two reasons phosphor-soluble actinomycetes have attracted ample attention: first, their ability to produce active agricultural metabolites, such as phytohormones, siderophores, etc. Second, for their ability to withstand various stresses. Furthermore, inoculation of actinomycetes with plants has also increased plant growth (Saif *et al.*, 2014).

3.4 Dry weight allocation coefficient to vegetative and seed parts

The results of the analysis of variance related to the effect of genotype on the allocation coefficient of dry weight on the shoot and seed parts are furnished in Table 4. Results indicated a significant effect of genotype on the allocation of dry weight to the shoot and seed parts with a p-value of 0.01. However, the effect of biofertilizer and the interaction effect of genotype and biofertilizer did not indicate a significant effect on these traits (Table 3).

Table 3- Analysis of variance of the Effect of genotype, biofertilizer, and their interactions on dry weight allocation coefficient to vegetation and grain in different wheat and barley genotypes

Source of variation	Degree of freedom	Dry weight allocation coefficient to vegetative parts	Dry weight to grain allocation coefficient (percentage)
Genotype	13	162.53**	154.34
Biofertilizer	2	8.69^{ns}	8.20^{ns}
Genotype + biofertilizer	26	7.73^{ns}	7.84^{ns}
Error	84	8.66	7.58
Coefficient of Variation (%)	-	5.07	6.54

*, ** and ^{ns} are significant at 1%, 5%, and not significant, respectively

The results of comparing the mean of the main effect of genotype on dry weight allocation coefficient of shoot exhibited that the range of changes was 47.61% in the Lukht genotype to 63.75% in the Darya genotype; subsequently, the Ehsan genotype indicated higher allocation of dry weight on shoot part with 63.28%. This indicated a 33% change in the dry weight allocation coefficient to the shoots (Table 4).

Table 4: Results of comparing the mean of the main effect of genotype on dry weight allocation coefficient to vegetative and wheat and barley

Genotypes	**Dry weight allocation coefficient to vegetative part (percentage)**	**Dry weight to grain allocation coefficient (percentage)**
Darya	63.7^{a}	$36/2^{f}$
Ehsan	63.2^{ab}	36.7^{ef}
Gonbad	62.6^{abc}	37^{def}
Karim	60.8^{bc}	39.1^{de}
Marwarid	61.3^{abc}	38.6^{def}
N-91-17	57.6^{d}	42.3^{c}
N-91-8	62.1^{abc}	37.8^{def}
N-91-9	60.4^{cd}	39.5^{cd}
Sahra	53.3^{e}	46.6^{b}
Torkman	51.9^{e}	48.0^{b}
Yusof	53.4^{e}	46.5^{b}
Boomy	60.4^{bcd}	39.5^{cde}
Lukht	47.6e	52.3a
Mahor	52.2e	47.7b
LSD	2.8	2.8

Regarding the coefficient of dry weight allocation to grain, the range of changes was between 36.24% in the Ehsan genotype to 52.38% in the Lukht genotype (Table 4). Several studies revealed a relation between shoot dry weight and inoculation of biofertilizers. (Cockmoxy *et al.*, 2007) found that barley's (*Hordeum vulgare L.)* shoot dry weight has increased up to 28.8 to 45.2% as a result of inoculating to growth bacteria. **(**Gholami *et al.,* 2009**)** also concluded that several parameters of shoot part weight are influenced by growth bacteria.

4. Conclusion

The results of this study revealed that the effect of genotype on all traits considered in this study (leaf dry weight, stem, root, shoot, and total) was significant at a 1% level of confidence and among the two plants studied, barley (Boomy, Sahara, Torkman, Mahor) had higher amounts of dry weight. Concerning the effect of biofertilizer, there was no significant relationship between dry weight and biofertilizers; however, the interaction effects of genotype and biofertilizer showed a significant effect and that the Marwarid genotype had the highest amount of root dry weight when actinomycete was applied.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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