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Full Length Research Paper

The effect of different humic acid fertilization on yield and yield components performances of common millet (*Panicum miliaceum* L.)

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Organic matter is a fundamental in soil, but dynamic component of soils that influences the many chemical, physical and biological properties that regulate soil productivity. Objective of using humic substances in plant is to balance vegetative and reproductive growth as well as to improve herbage and protein yield. This study has been carried out at the experimental area of the Field Crops Department of Dicle University, Agricultural Faculty in 2005 to 2006, to determine the effects of different humic acid treatments (Control, Soil 100%, Seeds 100%, Leafs 100%, Soil 50%+Seeds 50%, Soil 50%+ Leafs 50%, Seeds 50%+Leafs 50% and Seeds 33%+Soil 33%+Leafs 33% fertilizations) on yield and yield performances of common millet. According to results of the study, humic acid treatments raised the yield and yield components, and this raising was found to be significant statistically. The highest value for plant heights, bunch lengths, grain yields, 1000 grain weight, crude protein concentrations and grain number per bunch were obtained from leafs (100%) fertilizations and the highest hectoliter weight was obtained from seeds (100%) fertilizations.

Key words: Common millet, humic acid, fertilization, grain yield, crude protein

INTRODUCTION

Common millet was among the world's most important and ancient domesticated crops. It was the staple food in the semiarid regions of East Asia (China, Japan, Russia, India, and Korea) and even in the entire Eurasian continent before the popularity of rice and wheat (Bellwood, 2005; Crawford, 2005), and is still an important food in these regions today (You, 1993).

Common millet (or proso millet=broom corn millet) is grown in the world for use in commercial mixes of bird seed and for livestock feed. Nowadays, it is utilised like human food mainly in developing countries. In Europe, the grain is usually used as feed for pets. The renewed interest in the proso exploitation f or human food in developed countries was caused by health reasons (Kalinova and Moudry, 2006).

Crop production productivity is the basis of certain nutrients for human life which depends on amount of available nutrient in the soil. To improve the organic contents of soils for growing crops there are some applications such as planting rotation, various plough techniques, green fertilizer application and animal fertilizer application. In addition to these practices, utilization of organic-mineral fertilizers in agriculture has increased in recent years (Doran et al., 2003).

One of the used organic-mineral fertilizers is humic acid. Humic acid is one of the major components of humic substances. Humic matter is formed through the chemical and biological humification of plant and animal matter and through the biological activities of micro-organisms (Anonymous, 2010). The effects of humic substances on plant growth depend on the source and concentration, as well as on the molecular fraction weight

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of humus. Lower molecular size fraction easily reaches the plasma lemma of plant cells, determining a positive effect on plant growth, as well as a later effect at the level of plasma membrane, that is, the nutrient uptake, especially nitrate. The effects on intermediary metabolism are less understood, but it seems that humic substances may influence both respiration and photosynthesis (Nardi et al., 2002).

Humic substances have a very profound influence on the growth of plant roots. When humic acids and fulvic acids are applied to the soil, enhancement of root initiation and increased root growth may be observed (Pettit, 2004). The stimulatory effects of humic substances have been directly correlated with enhanced uptake of macronutrients, such as nitrogen, phosphorus and sulfur (Chen and Aviad, 1990), and micronutrients, that is, Fe, Zn, Cu and Mn (Chen et al., 1999).

Humic substances have been reported to influence plant growth both directly and indirectly. The indirect effects of humic compounds on soil fertility include.

(i) Increase in the soil microbial population including beneficial microorganisms.
(ii) Improved soil structure.
(iii) Increase in the cation exchange capacity and the pH buffering capacity of the soil.

Directly, humic acid compounds may have various biochemical effects either at cell wall, membrane level or in the cytoplasm, including increased photosynthesis and respiration rates in plants, enhanced protein synthesis and plant hormone like activity (Chen and Aviad, 1990). Humic substances may possibly enhance the uptake of minerals through the stimulation of microbiological activity (Mayhew, 2004). When adequate humic substances are present within the soil, the requirement for nitrogen, phosphorus and potassium fertilizer applications may be reduced (Pettit, 2004). Humic substances are major components of organic matter, often constituting 60 to 70% of the total organic matter (Schnitzer and Khan, 1972).

It will be possible to know which doses and application forms of plant regulators can be used with accurate application form and doses to achieve an increase in efficiency.

In this study, we aimed to determine the most appropriate method for the application of humic acid for common millet breeding as yield and yield components. In this regard, humic acid fertilizer application in the production of common millet which is known to be more efficient in terms of production would serve as a resource.

MATERIALS AND METHODS

In this study, *Panicum miliaceum L.* a variety of local populasyon, is used as the material. This study was carried out during the growing seasons of 2005 and 2006 in Diyarbakir, Turkey (37°54′N and 40°14′E) Experimental area was located at 660 m elevation. The field trial was arranged in complete randomized block design with four replications and it was grown on plots (size of one plot: 4 ×1.2 m). In both years, planting was made based on the calculation of 3 kg ha^{-1} seeds during the first week of June.

Generally, Mediterranean and East Anatolian continental climates are dominant in this region. The average annual temperature is 15.8°C, total rainfall is 481.6 mm and the average relative humidity is about 53.8%. The average temperature can reach 30°C in July and August. The lowest average temperature can be 7°C in December and January. The earliest frost in the region is usually at the end of October and the last frost around end of April. Most rainfalls in winter, and there is almost no rainfall from July to September. The highest humidity (70%) occurs in winter, lowest (27%) in summer. During the 2005 to 2006 years when the field trials were conducted, average temperature values were parallel to average values for long years, with no observation of any value that would negatively affect the plant development. The soils of the experimental area were thinly structured alluvial material (pH 7.7 to 7.9) or limestone (7.76 to 8.72%). The soil is low in organic material (1.67%) and phosphorus and has adequate calcium and high clay content (49 to 67%) in the 0 to 150 cm profile.

Treatment material used in this study was liquid humic acid (humic acid 40%, fulvic acid 25%). Humic acid was applied by eight different treatments (Control, soil 100%, seeds 100%, leafs 100%, soil 50%+seeds 50%, soil 50%+ leafs 50%, seeds 50%+leafs 50% and seeds 33%+soil 33%+leafs 33% fertilizations). The study was conducted with four replications according to the randomized complete block design.

Treatments

Control: No fertilizer application was made to these plots.
Soil 100%: 400 g of fertilizer was applied to soil in these plots; all of the fertilizers were administered to the soil when the plants reached 10 cm length.
Seeds 100%: 300 g of fertilizer was applied to seeds in these plots; all of the fertilizers were applied to the seeds during sowing.
Leafs 100%: 150 g of fertilizer was applied to leaf in these plots; all of the fertilizers applied to the leafs were administered when the plants reached 10 cm length. Soil 50% + Seeds 50%: 200 g of fertilizer applied to the soil was administered when the plants reached 10 cm length, and then 150 g of fertilizer was applied when sowing the seeds Soil 50% + Leafs 50%: 400 grams of fertilizer were administered to the soil and leafs when plants reached 10 cm length.

Seeds 50% + Leafs 50%: At first, 150 grams of fertilizer were applied to the seeds during sowing, and then 75 grams of fertilizer were administered to the leaf when plants reached 10 cm length.
Soil 33% + Seeds 33% + Leafs 33%: At first, 100 grams of fertilizer were applied to seeds at sowing, and then 100 grams of fertilizer were applied to the soil and 50 grams of fertilizer were applied to the leaf when plants were 10 cm in length.

Plant height, bunch length, grain yield, 1000 grain yield, crude protein concentration in grain, hectoliter weight and grain number per bunch were investigated in this study. Data was analyzed according to the randomized complete block design using the MSTAT-C statistical software. Where the difference between the treatments were significant, this difference was compared by Duncan multiple comparison method (MSTAT-C, 1991).

RESULTS

Plant height (cm)

The differences between treatments with respect to the

Table 1. Plant height (cm) of common millet in 2005 and 2006.

Treatments	2005	2006	Average
Control	67.60	65.60	66.60 c
Soil 100%	74.73	70.40	72.57 ab
Seeds 100%	70.27	68.80	70.03 a-c
Leafs 100%	74.60	71.40	73.00 a
Soil 50%+Seeds 50%	71.27	68.50	69.88 a-c
Soil 50%+Leafs 50%	73.53	69.90	71.72 ab
Seeds 50%+Leafs 50%	68.00	68.20	68.10 bc
Soil 33%+Seeds 33%+Leafs 33%	69.20	69.70	69.45 a-c
LSD	N.S.	N.S.	4.04*
CV	4.80	4.94	4.87

*, **: Means having same letter in the same column are non-significantly different (P< 0.05).

Table 2. Bunch length (cm) of common millet in 2005 and 2006.

Treatments	2005	2006	Average
Control	20.60 c	21.20	20.90 c
Soil 100%	24.00 ab	24.60	24.30 ab
Seeds 100%	22.20 bc	22.00	22.10 bc
Leafs 100%	25.20 a	23.90	25.05 a
Soil 50%+Seeds 50%	22.40 bc	21.80	22.10 bc
Soil 50%+Leafs 50%	23.13 bc	22.70	22.92 a-c
Seeds 50%+Leafs 50%	23.00 bc	22.80	22.90 a-c
Soil 33%+Seeds 33%+Leafs 33%	22.53 bc	21.90	22.22 bc
LSD	2.34**	N.S.	2.10*
CV	5.80	9.42	7.79

*, **: Means having same letter in the same column are non-significantly different (P< 0.05).

plant height value of common millet were found significant for average years. Data of first and second years were found non significant (Table 1).

In 2005 and 2006, the highest plant height was obtained from the treatment of leafs (100%), while the lowest plant height was obtained from the control. When the average of over two years was calculated, the treatment of leafs (100%) gave a significantly higher plant height (73.00 cm) than the control (66.60 cm) and other treatments.

Bunch length (cm)

The differences between treatments with respect to the crude protein concentration of common millet were found significant for the first year and average of these years. Data of second year was found non significant (Table 2).

In 2005, the highest bunch length was obtained from the treatment of leafs (100%) (25.20 cm), while the lowest bunch length was obtained from the control (20.60 cm). When the average for over two years was calculated, the treatment of leafs (100%) gave a significantly higher bunch length than the other treatments.

Grain yield (kg ha^{-1})

The differences between treatments with respect to the grain yield value of common millet were found significant for each two years and average of these years (Table 3).

In 2005 and 2006, when the average for over two years was calculated, the treatment of leafs (100%) gave a significantly higher grain yield (50.37, 41.85 and 46.11 kg ha^{-1} respectively) than the control (30.07, 31.02 and 30.55 kg ha^{-1} respectively).

1000 grain weight (g)

The differences between treatments with respect to the1000 grain weight of common millet were found significant for each two years and average of these years (Table 4).

Table 3. Grain yield (kg ha^{-1}) of common millet in 2005 and 2006.

Treatments	2005	2006	Average
Control	30.07 d	31.02 c	30.55 c
Soil 100%	47.87 ab	40.02 ab	43.95 a
Seeds 100%	30.64 d	37.02 b	33.83 c
Leafs 100%	50.37 a	41.85 a	46.11 a
Soil 50%+Seeds 50%	38.29 c	37.55 b	37.92 b
Soil 50%+Leafs 50%	41.50 bc	38.61 ab	40.06 b
Seeds 50%+Leafs 50%	38.90 c	38.08 b	38.49 b
Soil 33%+Seeds 33%+Leafs 33%	38.46 c	40.12 ab	39.29 b
LSD	6.51**	3.40**	3.51**
CV	9.41	5.10	7.65

*, **: Means having same letter in the same column are non-significantly different (P< 0.05).

Table 4. 1000 grain weight (g) of common millet in 2005 and 2006.

Treatments	2005	2006	Average
Control	4.73 c	4.60 d	4.67 b
Soil 100%	5.62 a	5.70 ab	5.66 a
Seeds 100%	4.81 c	5.10 b-d	4.95 b
Leafs 100%	5.36 ab	5.80 a	5.58 a
Soil 50%+Seeds 50%	5.50 a	5.30 a-c	5.40 a
Soil 50%+Leafs 50%	5.49 a	5.50 a-c	5.49 a
Seeds 50%+Leafs 50%	4.84 c	5.20 a-d	5.02 b
Soil 33%+Seeds 33%+Leafs 33%	4.97 bc	4.90 cd	4.94 b
LSD	0.45**	0.58**	0.35**
CV	4.94	6.32	5.69

*, **: Means having same letter in the same column are non-significantly different (P< 0.05).

In the first year, When the average for over two years was calculated, the treatment of soil (100%) gave significantly the highest 1000 grain weight (5.62 and 5.66 g respectively) while in the second year the treatment of leafs (100%) gave the highest 1000 grain yield (5.80 g)..

Crude protein concentration (%)

The differences between treatments with respect to the crude protein concentration of common millet were found significant for each two years and average of these years (Table 5).

In 2005, 2006 and average two years the treatment of leafs (100%) gave significantly higher crude protein concentration (10.00, 9.89 and 9.95% respectively) than the control (7.43, 7.67 and 7.55 g respectively).

Hectoliter weight (kg)

The differences between treatments with respect to the hectoliter weight value of common millet were found significant, when the average for over two years was calculated, Data of first and second years were found non significant (Table 6).

In 2005 and 2006, the most hectoliter weight was obtained from the treatment of seeds 100%, while the lowest hectoliter weight was obtained from the control. Averaged over two years, the treatment of Seeds 100% gave a significantly higher hectoliter weight (62.60 kg) than the control (58.94 kg) and other treatments.

Grain number per bunch (item)

The differences between treatments with respect to the grain number per bunch of common millet were found significant for each two years and average of these years (Table 7).

In the first year and second year, When the average for over two years was calculated, the treatment of leafs (100%) gave significantly higher grain number per bunch (907.9, 900.1 and 904.0 item respectively) than the

Table 5. Crude protein concentration in grain (%) of common millet in 2005 and 2006.

Treatments	2005	2006	Average
Control	7.43 e	7.67 c	7.55 f
Soil 100%	9.47 ab	9.20 b	9.33 b
Seeds 100%	7.90 de	8.10 c	8.00 e
Leafs 100%	10.00 a	9.89 a	9.95 a
Soil 50%+Seeds 50%	8.80 c	8.75 b	8.78 cd
Soil 50%+Leafs 50%	9.10 bc	8.88 b	8.99 bc
Seeds 50%+Leafs 50%	9.07 bc	9.01 b	9.04 bc
Soil 33%+Seeds 33%+Leafs 33%	8.17 d	8.80 b	8.48 d
LSD	0.59**	0.58**	0.40**
CV	3.85	3.74	3.79

*, **: Means having same letter in the same column are non-significantly different (P< 0.05).

Table 6. Hectoliter weight (kg) of common millet in 2005 and 2006.

Treatments	2005	2006	Average
Control	58.47	59.41	58.94 b
Soil 100%	60.31	61.35	60.83 ab
Seeds 100%	62.35	63.07	62.60 a
Leafs 100%	62.16	59.16	60.66 ab
Soil 50%+Seeds 50%	57.95	59.71	58.83 b
Soil 50%+Leafs 50%	58.79	60.16	59.47 b
Seeds 50%+Leafs 50%	61.56	60.24	60.90 ab
Soil 33%+Seeds 33%+Leafs 33%	62.13	62.30	62.22 a
LSD	N.S.	N.S.	2.11**
CV	3.20	2.66	2.94

*, **: Means having same letter in the same column are non-significantly different (P< 0.05).

control (631.3, 674.2 and 652.8 item respectively) and other treatments.

DISCUSSION

The use of the humic substance has been on the increased in recent years. Improvement of soil conditions and establishing equilibrium among plant nutrients are also important for soil productivity and plant production. Humic substances and organically improvement of soil increased the yields of some field crops in several studies (Ulukan, 2008). Duplessis and Mackenzie (1983) found that it increases the grain yield of legumes such as mung bean (mash bean=moong) (*Vigna radiata* L.), soybean (*Glycine max* L.) and pea (*Pisum sativum* L.) (Iswaran et al., 1980) by using them. It was reported that the increase in grain yield was believed to be due to phenolic compounds that were toxic to soil bacteria and protozoa that are antagonistic towards *Rhizobium* species (Bhardwaj and Gaur, 1971). But, some study results are different from them. According to their results, this application is ineffective in maize and bean yields (Adriano et al., 1978), yield and quality in potatoes (Rowberry and Collin, 1977). These studies have been conducted on the Fe and Al densely soils, so this type of the soils inactivates the humic acid's effect. However, Tan and Nopamornbodi (1979) were found that humic acid decreased the P concentration in the maize plants. Researcher explained that this situation was due to the reaction of P with the phenolic functional groups on the humic acid ion. Studies have sown that humic acid are capable of forming complexes with P that are unavailable to the plant. Phosphorus is very important in the early seedling development phase of most vegetable and row crops.

Albayrak and Camas (2005) obtained the highest root and leaf dry matter yields from the 1200 ml ha^{-1} humic acid level and after two month of sowing date application onto leaves in forage turnip (*Brassica rapa* L.) crop. Foliar spray with humic acid also increased root length (Malik and Azam, 1985) and leaf area index (Figliolia et al., 1994). Kolsarici et al. (2005) discovered that 60 g humic acid per 100 seeds produced the highest values for the all criteria and they recommended that this ratio could be used for all cultivated sunflower (*Helianthus annus* L.)

Table 7. Grain number per bunch (item) of common millet in 2005 and 2006.

Treatments	2005	2006	Average
Control	631.3 d	674.2 e	652.8 d
Soil 100%	670.1 cd	854.3 bc	762.2 c
Seeds 100%	836.8 ab	792.9 d	814.8 bc
Leafs 100%	907.9 a	900.1 a	904.0 a
Soil 50%+Seeds 50%	740.8 bc	808.5 cd	774.7 bc
Soil 50%+Leafs 50%	809.1 ab	841.3 bc	825.2 b
Seeds 50%+Leafs 50%	764.0 bc	828.3 cd	796.2 bc
Soil 33%+Seeds 33%+Leafs 33%	754.1 bc	876.4 ab	815.3 bc
LSD	102.5**	43.30**	53.11**
CV	7.65	3.01	5.66

*, **: Means having same letter in the same column are non-significantly different ($P< 0.05$).

varieties.

Erdal et al. (2000) reported that the dry weight, plant P concentration, P uptake and residual available P amount increased with humic acid applications, and that the effect of humic acid on the above parameters combined with P fertilization was higher than that of humic acid alone. Oren and Basal (2006) reported that the application method of humic acid did not significantly affect investigated characters; however, application dose had significant and positive effect on earliness, one hundred seed weight, boll weight and yield and the best result was obtained by underground application by dose of 2000 g ha^{-1} in cotton (*Gossypium hirsutum* L.). Kaya et al. (2005) reported as compared to the control, combined zinc and foliar humic acid or zinc and separate applications have increased the grain yield of bread wheat. Kalinova and Moudry (2006) found out that the crude protein concentration is 12.12-13.72%.

Conclusion

When the two years average values are taken into consideration, different humic acids applications significantly and statistically affected the investigated characters and it caused an increase when compared with control plots.

According to results of the study, humic acid treatments raised the yields, and this raising was find to be statistically significant as the highest value for plant heights, bunch lengths, grain yields, 1000 grain weight, crude protein concentrations and grain number per bunch were obtained from leafs 100 %fertilizations and the highest hectoliter weight was obtained from seeds 100% fertilizations.

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