Effects of Nitrogen Doses on Yield and Some Traits of Proso Millet (*Panicum miliaceum* L.) in Highlands

Mustafa Tan, Habip Olak, and Taşkın Öztaş
Atatürk University Faculty of Agriculture, Erzurum, Turkey
Email: {mustan, toztas}@atauni.edu.tr, habipolak_zm@hotmail.com, @atauni.edu.tr

***Abstract*—Crop production and plant diversity are low due to short development period and low temperature in highlands. This research was conducted to determine the effects of different nitrogen doses on yield and some traits of proso millet (*Panicum miliaceaum* L.) in altitude of 1860m Eastern Anatolia conditions. The experiment was established in a randomized complete blocks design with four replications in 2013 and 2014. Five nitrogen doses (0, 30, 60, 90 and 120kg N ha^{-1}) were used in this study. Plant height, dry matter yield, crude protein content and yield, ADF and NDF content, biological, seed and straw yield, harvest index and 1000-seed weight were evaluated. In summary, this 2-year study clearly showed that irrigated proso millet can be successfully produced in Eastern Anatolia conditions. The results indicated that nitrogen doses had significant effects on the yields and increased the plant height, dry matter yield, crude protein content and yield, biological yield, seed yield and straw yield. The highest dry matter yield (4640kg ha^{-1}) and seed yield (2699kg ha^{-1}) were determined in 90kg N ha^{-1}, whereas the highest biological yield (7466 kg da^{-1}) was determined in 120kg N ha^{-1}.**

***Index Terms*—proso millet, nitrogen fertilization, dry matter yield, seed yield, hay quality, plant characteristics**

I. INTRODUCTION

High-altitude regions have short cultivation period, cold and long winter months and relatively cool summer period. In this ecology, cool-season crops are mostly taken into account when the diversification of species that are cultivated is aimed. Those that firstly come to mind among annual species used for hay production are vetches (*Vicia* sp.) from legumes, and ryegrasses (*Lolium* sp.) and cool-season cereals from grasses. However, some species of warm seasons with short development time and fast growth rate can give successful results at higher altitudes. For example, corn (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. (Monech.)) are two species has a wide tolerance despite being a subtropical climate plant, and its cultivation is possible as silage in Erzurum [1], [2].

Occasionally, on agricultural areas, crop seeding is delayed for various reasons or it is required to cancel the planted products and to plant new products on cropland. After this period coinciding with the beginning of the hot summer months, cool-season plants cannot give enough yields. Plant species with a short vegetation period to be cultivated in this period are needed. When it is considered within this scope, plants that first come to mind are millets (Panicum sp.) in high altitude regions. Panicum is a large genus of about 450 species of grasses native throughout the tropical regions of the World [3], [4]. There are a few species growing in the northern temperate zone. These plants are annuals and perennials; many are tufted or have underground stems. Many species of *Panicum,* known as millet or panicgrass, are cultivated in Asia and Europe as crop plants and in the United States for forage, livestocks feed, and birdseed.

One of the millet species that are commonly cultured in the world is the proso millet (Panicum miliaceum L.). This is annual millet species scattered throughout the world's warm and temperate regions. Stems are light green, erect, sometimes branched at the base, and grow 0.5-1.5 m tall. Plants have shallow, fibrous root systems and produce few tillers. It is used as cereal since ancient times. It is one of the oldest plants in Europa and Asia. It is thought that proso millet was originally cultivated in eastern Asia, later spreading to India, Russia, the Middle East, and Europe [5]. Today it is produced in India, China, Russia, and the Middle East. In the United States, it is mainly grown in the Great Plains states of Nebraska, South Dakota, and Colorado, with limited production in Kansas, Wyoming, and Minnesota. US production has increased in the past 10 years [6].

Proso millet is grown for livestock and birdseed similar to other millets species. The feed value of proso millet for cattle and swine is generally considered to equal that of grain sorghum or corn [7]. It has been used as health food, and due to its lack of gluten, it can be included in the diets of people who cannot tolerate wheat.

Proso millet is well adapted to many soil and climatic conditions; it has a short growing season, and needs little water. It matures quickly, in 60-100 days [8], [9]. Baltensperger [5] was reported, it can be grown farther north than other millets and is adapted to high elevation plateaus and poor soil. It has a shallow wibrous root system, therefore it does not grow well under water stress. It is not frost-tolerant and does not grow well in soils

Manuscript received February 17, 2016; revised July 27, 2016.

doi: 10.18178/joaat.3.4.301-304

with a pH greater than 7.8 [10]. Proso millet is a good plant for rotation in arid areas; it has been used in a winter – wheat – sunflower – proso - fallow rotation in the Great Plains [7].

Nitrogen fertilization is essential for production and quality of grasses, since there is usually the lack of organic matter and plant-available nitrogen on agricultural lands. Therefore, soil nutrient balance should be maintained to get higher yields from the plants. The amount of N needed depends on several factors such as climate, soil productivity, and management. When it is considered within this scope, nitrogen fertilizer application is needed in millet cultivation in poor soils. Proso millet also requires additional nitrogen. It planted fallowing another crop, such as wheat, has a higher nitrogen requirement than after summer fallow [7]. However, the amount of fertilizer dose to be applied is very important. Because higher rates typically lead to lodging. Fertilization studies carried out in different parts of the world suggest 45-225kg N ha-1 for hay and seed yields in millets [8], [11]-[13]. Since research information is lacking, the study was conducted to determine the effects of different doses of nitrogen fertilizers on hay and seed yield and plant characteristics of proso millet, which would be experienced for the first time in Eastern Anatolia Region, the high altitude region of Turkey.

II. Materials and Methods

The research was carried out at the irrigated experiment field of Atatürk University Faculty of Agriculture in Erzurum, Turkey in 2013 and 2014. In the research, proso millet (*Panicum miliaceum* L.) landrace was fertilized with 5 different doses of nitrogen (0, 30, 60, 90 and 120kg N ha^{-1}). The experiment was established in a randomized complete blocks design with four replications. Field experiments were established in May in both years; the hay was harvested in July and seeds were harvested in August.

Seeding was performed with a row spacing of 20cm, parcel length of 3m and parcel width of 1.6m (8 rows). 30 kg ha^{-1} seed were seeded into the pre-prepared seed bed at a soil depth of 2-3cm with hand drills [9], [14]. Plants were harvested for hay when they reached 50% of the flowering period and for seed in the full ripening period. While the half of the parcels was harvested for hay, the other half was harvested for seed.

Dry matter, seed, straw, biological and crude protein yield, crude protein, ADF and NDF contents of hay and plant height were determined. Plant height measurements were made on 10 plants selected randomly from the midsection of each parcel before hay harvesting. Dry matter yields were determined by drying grass harvested from the parcels firstly in the open air and then in a drying oven set at 65 ℃ for 48 hours. While crude protein content was determined by the Kjeldahl method [15], the ADF and NDF contents were determined in ANKOM Fiber Analyzer according to the guidelines specified by Van Soest [16]. Plants harvested for seed were dried firstly in the open air and then in a drying oven at 40 ℃ and were weighed; firstly biological yields, and after threshing seed yield and straw yields were calculated. Dry matter, biological and seed yields were determined by hand-clipping 1.2m^2 areas from each plot.

The data obtained were tested to the analysis of variance with the MSTAT-C package program according to the randomized complete blocks experimental design, and differences between averages which were found significant were showed by the LSD test [17].

The texture of the experiment soil is clay loam, and total salt was 0.06%, pH was 7.45, lime was 1.3%, plant-available P_2O_5 was 54kg ha^{-1}, K_2O was 1740kg ha^{-1}, and organic matter was 0.97% (Table I). According to these values, the experiment soil is salt-free, slightly alkaline, light calcareous, poor in plant-available phosphorus, rich in potassium and very poor in organic matter [18].

TABLE I. Some Physical and Chemical Properties of the Experiment Soil

Property	Value
Texture class	Clay-loam
Salinity	0.06 %
pH	7.45
$CaCO_3$	1.3 %
Organic matter	0.97 %
Available P_2O_5	54 kg ha^{-1}
Available K_2O	1740 kg ha^{-1}

Erzurum is located at 39°55′N, and 41°61′E at an altitude of 1860m in Eastern Anatolia, Turkey. It has a continental climate with cold, snowy winters and warm, dry summers. There is a large temperature difference between summer and winter and day and night because of its high altitude and continental climate. Most precipitation occurs in winter and spring. The average maximum daily temperature during August is around 27 ℃. However, the average minimum daily temperature during January is around −15 ℃; temperatures fall below −30 ℃ most years. In the experiment periods (May-August) of the province in 2013 and 2014, the monthly average relative humidity, the average temperature, and the total rainfall value were 54.2%, 52.5%; 16.4 ℃, 17.2 ℃ and 65.7 and 141.6 mm, respectively (Table II). While the relative humidity and temperature values were close to each other in both years, the total amount of rainfall was lower in 2013. As the experiment was carried out in irrigated conditions, years has had no statistically effect on the experiment data, and the results were given as the two-year average.

TABLE II. Some Climatic Data of the Research Location and Research Period (May-August) in 2013 and 2014 at Erzurum, Turkey

Months	Humidity (%)		Temperature (℃)		Precipitation (mm)	
	2013	2014	2013	2014	2013	2014
May	63.5	68.7	11.6	11.3	29.0	88.6
June	57.2	54.9	15.0	15.3	23.9	21.6
July	50.4	46.9	19.4	20.5	7.4	27.8
August	45.7	39.6	19.5	21.5	5.4	3.6
Mean/Tot.	54.2	52.5	16.4	17.2	65.7	141.6

III. Results and Discussion

The results of this study clearly indicated that nitrogenous fertilizer doses had statistically significant effects on plant height, dry matter yield, crude protein yield and crude protein content of proso millet, but had no significant effects on the ADF and NDF contents of the hay (Table III, Fig. 1 and Fig. 2, Fig. 3).

TABLE III. Dry Matter Yield and Some Properties of Proso Millet Fertilized with Different Doses of Nitrogen[1]

N doses (kg-N ha^{-1})	Plant Heig. (cm)	Dry Mat. Yield (kg ha^{-1})	C.Prot. (%)	C.Prot Yield (kg ha^{-1})	ADF (%)	NDF (%)
0	51.4 b	2924 b	12.39 b	338 b	36.05	58.40
30	56.6 ab	4017 ab	13.20 ab	531 ab	35.80	59.76
60	64.3 ab	4030 ab	13.16 ab	533 ab	35.73	58.09
90	70.7 a	4640 a	13.57 ab	631 a	36.73	60.02
120	66.3 ab	4639 a	14.24 a	656 a	36.10	59.82
Mean	61.9	4050	13.31	538	36.08	59.22
F-Test						
LSD	18.9 **	1170 *	1.51 *	200 *	ns	ns

[1]Means within a column marked by the same letters are not significantly different.
ns: no significance; *: $p< 0.05$; **: $p< 0.01$.

Plant height increased in parallel to the applied nitrogen fertilizer doses, and the highest plant height was determined in 90kg N ha^{-1} dose (70.7cm). Similarly, it is seen that the dry matter yield increased with the increase of nitrogen doses. While the lowest dry matter yield (2924kg ha^{-1}) was obtained from the control parcels without nitrogen application, the highest yields were obtained from 90 and 120kg N ha^{-1} applications (4640 and 4639kg ha^{-1}). Nitrogen fertilizer applications increased the crude protein content of the hay and accordingly the crude protein yield. The highest crude protein content (14.24%,) and crude protein yield (656kg ha^{-1}) were determined in 120kg N ha^{-1} application (Table III, Fig. 1 and Fig. 2).

The grasses have high nitrogen consumption. In the soils with the insufficient organic matter, the fact that nitrogen fertilizer application increases the vegetative part and accordingly the dry matter yield is a natural result. The optimal root development in proso millet occurs in 80-120kg N ha^{-1} doses [19]. It has been determined in various researches that the nitrogen fertilizer application increased the dry matter yield [13], the crude protein content [20], [21], and the crude protein yield [8] in Panicum species. Baltensperger *et al.* [22] suggested that, when proso millet follows wheat, it is generally recommended that 45kg ha-1 of nitrogen be applied. Chadhari and Rai [23] suggest that 40 kg N ha-1 used for obtaining a good crop of proso under irrigated conditions in India.

Nitrogen doses significantly affected the biological yield, seed yield and straw yield of proso millet (Table IV, Fig. 1). Yields were observed to be low in control parcels without nitrogen application. The highest biological yield (7466kg ha^{-1}) and straw yield (4856kg ha^{-1}) were obtained in 120kg N ha^{-1} dose which is the highest nitrogen dose. Seed yield reached the maximum in 90kg N ha^{-1} application. However, the seed yields of 30-120kg N ha^{-1} doses (2423-2610kg N ha^{-1}) were into the same group statistically.

TABLE IV. Seed Yield and Some Properties of Proso Millet Fertilized with Different Doses of Nitrogen[1].

Nitrogen Doses (kg N ha^{-1})	Biol. Yield (kg ha^{-1})	Seed Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index (%)	1000-Seed Weight (g)
0	5122 c	1812 b	3311 b	35.3	6.69
30	6121 bc	2423 ab	3698 ab	39.7	6.67
60	6188 bc	2606 a	3582 ab	44.0	6.25
90	7017 ab	2699 a	3631 ab	38.9	6.30
120	7466 a	2610 a	4856 a	34.7	6.39
Mean	6383	2430	3816	38.5	6.46
F-Test					
LSD	1234 *	661 *	1308 *	ns	ns

[1]Means within a column marked by the same letters are not significantly different.
ns: no significance; *: $p< 0.05$

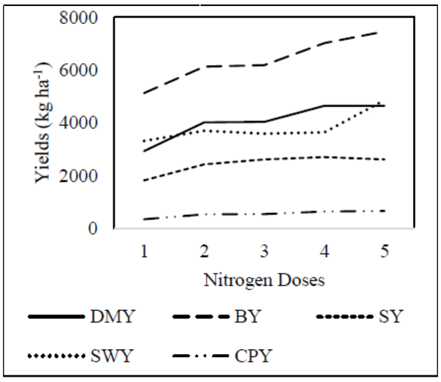

Figure 1. Dry matter (DMY), biological (BY), seed (SY), straw (SWY) and crude protein (CPY) yield of proso millet at different nitrogen doses.

Turgut *et al.* [8], [11] determined that biological yield and seed yield increased with nitrogen fertilization in proso millet and that the highest biological yield was obtained from 150kg N ha^{-1} dose, the highest seed yield was obtained from 225kg N ha^{-1} dose. Pointing to the similar results again, Hassan *et al.* [12] observed that the highest seed yield was in 60kg N ha^{-1} nitrogen dose in foxtail millet (*Panicum italicum*). Nitrogen fertilizer doses did not statistically affect the harvest index and 1000-seed weight of proso millet (Table IV, Fig. 3).

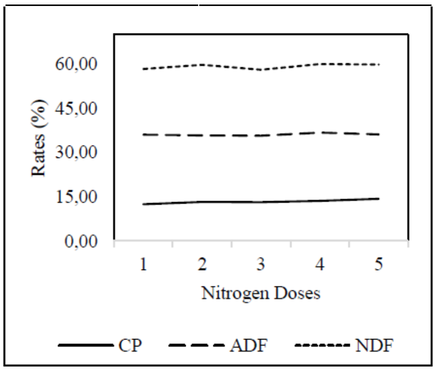

Figure 2. Crude Protein (CP), Acid Detergent Fiber (ADF) and Natural Detergent Fiber (NDF) rates of proso millet at different nitrogen doses.

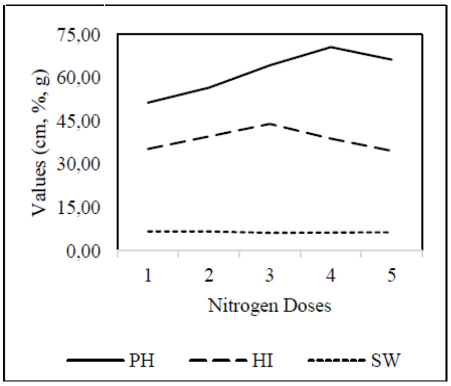

Figure 3. Plant Height (PH), Hatvest Index (HI) and 1000-Seed Weight (SW) of proso millet at different nitrogen doses.

IV. CONCLUSIONS

Two-year results obtained from this research have revealed that Panicum miliaceum can easily be grown for the production of hay and seed in Erzurum with high altitude. However, nitrogen fertilization is required in soils poor in organic matter. Considering that nitrogen is easily washed and leads to environmental pollution, it is useful to recommend doses as low as possible. According to the results of this study, sufficient yield can be obtained in hay and seed production by 30 kg N ha-1 application. Further studies on topics related to different form and application time of fertilizers should be done in the next stage.

ACKNOWLEDGMENT

This work was supported by Ataturk University Research Foundation (BAP-2013/384)

REFERENCES

[1] E. Güney, M. Tan, Z. D. Gül, and I. Gül, "Determination of yield and silage quality of some maize cultivars in Erzurum conditions," *J. Atatürk University Faculty of Agriculture*, vol. 41, no. 2, pp. 105-111, 2010.

[2] E. Güney, M. Tan, and İ. Gül, "Erzurum şartlarında silajlık amacıyla yetiştirilen bazı sorgum çeşitlerinin verim, bitkisel özellikler ve silaj kalitesi yönünden değerlendirilmesi," in *Proc. Türkiye VII. Tarla Bitkileri Kongresi*, Erzurum, 2007, pp. 353-356.

[3] Anonymous, "Panicum," Natural Resources Conservation Service Plants Database, USDA, 15 May 2015.

[4] A. S. Hitchcock, "Manual of grasses of the United States," United States Department of Agriculture, Miscellaneous Publications 200, 1950.

[5] D. D. Baltensperger, "Foxtail and proso millet," in *Progress in New Crops*, J. Janick, ed., Alexandria, VA: ASHS Press, 1996, pp. 182-190.

[6] S. K. McDonald, L. Hofsteen, and L. Downey. (2003). Crop profile for proso millet in Colorado. *USDA Crop Profiles, Regional IPM Centers.* [Online]. Available: http://www.ipmcenters.org/CropProfiles/

[7] D. J. Lyon, *et al.*, "Proso millet in the Great Plains," Publication EC137. Univ. of Nebraska Ext. Serv., Lincoln, NB, 2008.

[8] I. Turgut, A. Duman, G. W. Wietgrefe, and E. Acikgoz, "Effect of seeding rate and nitrogen fertilization on proso millet under dryland and irrigated conditions," *Journal of Plant Nutrition*, vol. 29, pp. 2119-2129, 2006.

[9] Y. Serin and M. Tan, "Forage grasses," Atatürk University Publ., Erzurum, Turkey, 2014, no. 859.

[10] C. M. Sheahan, "Plant guide for proso millet (*Panicum miliaceum)*," *USDA-Natural Resources*, 2014.

[11] I. Turgut, A. Duman, G. W. Wietgrefe, and E. Açıkgöz, "Sulu ve kuru koşullarında yetiştirilen kumdarı (*Panicum miliaceum* L.)'da ekim sıklığı ve azot dozlarının verim ve verim öğeleri üzerine etkisi," in *Proc. Türkiye 5. Tarla Bitkileri Kongresi*, Diyarbakır, 2003, pp. 293-297.

[12] S. M. E. Hassan, M. S. Rahman, M. F. Hossain, M. R. Amin, and M. M. Alam, "Evaluation of planting density and nitrogen on the performance of Kaon (*Setaria italica* (L). Beauv.)," *Pakistan Journal of Biological Sciences*, vol. 3, no. 11, pp. 1863-1864, 2000.

[13] S. B. Kalaghatagi, D. I. Jirali, S. Y. Wali, and M. S. Nagod, "Remove from marked records response of foxtail millet (Setaria italica) to nitrogen and phosphorus under rainfed conditions of northern dry zone of Karnataka," *Annals of Arid Zone (India)*, vol. 39, no. 2, pp. 169-171, 2000.

[14] E. Kün, "Sıcak iklim tahillari, Ankara Üniv. Ziraat Fak, Yay: 953, Ders Kitabı: 275, Ankara, 1985.

[15] B. Kacar, "Toprağın kimyasal analizleri: II. Bitki Analizleri," Ankara Üniv. Ziraat Fak, Yay, Ankara, no. 453, p. 464, 1984.

[16] P. J. V. Soest, "The use of detergents in the analysis of fibrous feeds. II. A rapid method for determination of the fiber and lignin," *JAOAC*, vol. 46, pp. 829-835, 1963.

[17] N. Yıldız and H. Bircan, "Uygulamalı İstatistik," *Atatürk Universitesi Yay*, no. 704, pp. 308-60, 1991.

[18] Anonymous, "Türkiye Toprakları Verimlilik Envanteri," *T.C. Tarım Orman ve Köy İşleri Bakanlığı. Köy Hizmetleri Genel Müdürlüğü*, Ankara, 1991.

[19] Z. Stypczyska and A. Dziamski, "Influence of sprinkling irrigation and diverse nitrogen fertilızation on the mass and distribution of millet (*Panicum miliaceum* L.) root system on a very light soil," *Acta Sci. Pol. Agricultura*, vol. 7, no. 1, pp. 93-101, 2008.

[20] J. Y. Jung and L. Lal, "Impacts of nitrogen fertilization on biomass production of switchgrass (*Panicum virgatum* L.) and changes in soil organic carbon in Ohio," *Carbon Management and Sequestration Center (C-MASC)*, School of Environment and Natural Resources, The Ohio State University, Columbus, OH 43210, USA, 2011.

[21] T. Namihira, N. Shinzato, H. Akamin, I. Nakamura, H. Maekawa, Y. Kawamoto, and T. Matsui, "The effect of nitrogen fertilization to the sward on guineagrass (*Panicum maximum* Jacq cv. Gatton) silage fermentation," *Asian-Aust. J. Anim. Sci*., vol. 24, no. 3, pp. 358-363, 2011.

[22] D. Baltensperger, *et al.*, "Producing and marketing proso millet in the high plains," EC 95-137-C, Univ. Nebraska, Lincoln, 1995.

[23] L. B. Chaudhari and B. Rai, "Production technology for proso millet," *Indian Farming*, vol. 82, pp. 13-16, 1982.

Mustafa Tan was born in Edirne, Turkey on 22 January 1967. He obtained M.Sc. and Ph.D. in forage crops from Atatürk University, Turkey in 1991 and 1995 respectively. He is working as a Professor in Atatürk University Faculty of Agriculture, Erzurum, Turkey. Prof. Dr. M. Tan is specialising in forage grasses, forage legumes, silage crops, etc. Now he works on alternative forage plants such as amaranth and quinoa.

Habip Olak is born in Şırnak, Turkey in 1987. He completed his undergraduate education in Atatürk University Faculty of Agriculture Department of Field Crops in 2012. He obtained M.Sc. in forage crops from Atatürk University in 2014. He is a specialist in forage grasses.

Taşkin Oztas is a professor at the Department of Soil Science and Plant Nutrition, Ataturk University, Turkey. He received his BSc (1985) and MS (1987) from Ataturk University, and completed his Ph.D.at the University of Nebraska-Lincoln, USA in 1993. His research interests are soil conservation and management, soil quality, soil degradation and geostatistics.