Range Mgmt. & Agroforestry 39 (2) : 237-242, 2018
ISSN 0971-2070

Forage growth and quality of pearl millet (*Pennisetum americanum* L.) as influenced by nitrogen and zinc levels in hyper arid region of Rajasthan

Vimal Khinchi*, **S. M. Kumawat and Mohd. Arif**
S. K. Rajasthan Agricultural University, Bikaner-334006, India
*Corresponding author e-mail: vk97agro@gmail.com
Received: 22nd January, 2017 Accepted: 4th August, 2018

Abstract

A field trial was conducted on sandy loam soils of Agronomy Farm at College of Agriculture, SKRAU, Bikaner during *kharif* season of 2014 to study the effect of nitrogen and zinc on growth, nutrient content and uptake, and quality of fodder pearl millet (*Pennisetum americanum* L.). Trial was consisted of 20 treatment combinations *viz.*, five nitrogen levels (0, 30, 60, 90 and 120 kg/ha), and four zinc sulphate doses (no zinc, 15, 30, 45 kg/ha). The experimental results indicated that application of nitrogen @ 90 kg/ha being at par with higher N dose (120 kg/ha) significantly increased all growth characters *viz*., plant height, number of leaves/plant, tillers/plant, leaf:stem ratio and chlorophyll content of leaves. Whereas, number of leaves/plant increased up to the highest N level of 120 kg/ha during both cutting stages in fodder pearl millet. The quality parameters namely crude protein and ether extract increased significantly with increasing nitrogen dose up to 120 kg/ha, but nitrogen free extract (NFE) and total digestible nutrient (TDN) content in fodder showed reverse trend and recorded the maximum values under control treatment at both the cuttings. Crude fiber and ash contents were found non-significant with increasing dose of nitrogen fertilizer. Application of zinc sulphate ($ZnSO_4$) up to 30 kg/ha significantly improved growth characters at both cutting stages. Moreover, the quality parameters also improved with doses of $ZnSO_4$ up to 45 kg/ha, but the differences between 0-15, 15-30 and 30-45 kg/ha were found statistically non-significant.

Keywords: Fodder quality, Growth parameters, Nutrient uptake, Pearl millet

Introduction

Pearl millet (*Pennisetum americanum* L.) is erect, leafy and drought resistant plant, widely used for grain production in arid and semi arid regions of India. This crop is not only cultivated for grain, but also valued for its stover as fodder purpose. Pearl millet as fodder crop has some additional advantages over sorghum and maize because of firstly, the green fodder of pearl millet has high crude protein content (9.9 to 14%) and secondly, its green fodder can be safely fed to cattle at all stages of growth because of absence of hydrocyanic acid. It is nutritious and palatable and can be fed as green, dry or as conserved fodder in the form of silage or hay. The more tillers production capacity, rapid growth rate and higher crude protein (CP) contents and short growth period make the pearl millet a strong cereal for fodder purpose. The nutritional quality of livestock feed resources is assessed by its dry matter, CP, fat, ash and crude fibre (CF) contents. The required concentration of these quality attributes in plant can be achieved with harvesting at optimal time and optimum plant nutrition factors such as nitrogen rates (Cecelia *et al*., 2007) and other micronutrients especially zinc application (Alloway, 2008).

Nitrogen is an essential nutrient for plant growth and development. It is a very important constituent of cellular components. Alkaloids, amides, amino acids, proteins, DNA, RNA, enzymes, vitamins, hormones and many other cellular compounds contain nitrogen as one of the elements. An adequate supply of nitrogen is associated with vigorous vegetative growth and deep green colour. Nitrogen is also an integral part of chlorophyll ($C_{35}H_{72}O_5N_4Mg$) and needed to improve the yield and quality of forage pearl millet. Judicious and appropriate use of fertilizer not only increases yield but also improves quality of forage especially protein content (Ayub *et al.,* 2007). Generally, pearl millet has been known for growing under low N management (Gascho *et al.,* 1995), but several studies showed that N application can increase millet production efficiency (Singh *et al*., 2010). Further, zinc is an imperative micronutrient. It is needed in small quantity, but plays indispensable role in various plant physiological processes such as photosynthesis, protein and sugar synthesis, fertility and production of seeds, growth regulation and disease immune system. It is the constituent of several enzyme systems which regulate various metabolic reactions in the plant. Singh (2009) reported that 49% soils in India are deficient in available Zn and the application of Zn is reported to increase cereals yield by 6.3-9.3%. Verma *et al*. (2005) observed that nitrogen and zinc affected growth, yield and quality in fodder sorghum. With this background, a field experiment was planned to study the effect of nitrogen and zinc on growth and quality of fodder pearl millet.

Materials and Methods

Experimental site and crop raising: A field experiment was conducted during *kharif* season 2014 on sandy loam soil at Agronomy Farm, College of Agriculture under SKRAU, Bikaner on fodder pearl millet variety AVKB-19. Total twenty treatment combinations comprising five nitrogen levels (0, 30, 60, 90 and 120 kg/ha), and four zinc levels (0, 15, 30, 45 kg $ZnSO_4$ per ha) were evaluated in factorial randomized block design with three replications. The soil had pH 8.4, EC 0.20 ds m^{-1} (1:2 solution) and organic carbon 0.11%, and available N, P, K were 93.85, 21.91 and 234.0 kg/ha, respectively. Sowing was done manually with *Kera* method on 24^{th} July, 2014 at onset of monsoon rain at row spacing 25 cm using seed rate of 10 kg/ha. Nitrogen fertilizer was applied in three splits *i.e*, one-third dose (as per treatment) and full dose of $ZnSO_4$ at sowing. The remaining two-third dose of nitrogen was top dressed in two splits equally *i.e*, first at 25 days after sowing (DAS) and rest dose about one week after first cutting (50 DAS) with sprinkler irrigation. Total rainfall 417 mm was received in 11 rainy days during the crop period and four irrigations were given by sprinkler system operated for three hours spaced at 6.0 m apart continuous nozzle arrangement with depth of 4.0 cm each. The crop was harvested for green fodder at 45 DAS (first cut) and at 90 DAS for second cut.

***Observations*:** Growth characters *viz*., plant height, leaf: stem ratio and number of leaves/plant were recorded in each plot from second inner row on both sides leaving the boarder row at both cutting stages adopting standard procedures. Chlorophyll content of leaves was worked out at 45 and 90 DAS by the method of Hiscox and Israelstem (1979). The forage nutritive value was analyzed in terms of CP, CF, EE, ash, NFE and TDN contents of dry matter using standard method (AOAC, 1990). The sub sample of dry matter was well grinded and passed through 0.5 mm sieve and preserved for chemical analysis. The ash contents were calculated keeping the samples in muffle furnace at 550°C for three hours. The nitrogen content was determined by Kjeldahl method and the value recorded for nitrogen was then multiplied with 6.25 (Jones, 1931) to determine CP of the sample. The ether extract contents were recorded by using Soxhlet apparatus.

***Statistical analysis*:** The data regarding different observations were analyzed using standard method of analysis for variance (ANOVA) for factorial randomized block design for field experiment as per Gomez and Gomez (1976).

Results and Discussion

Nitrogen levels

***Growth*:** Plant height, number of leaves/plant, number of tillers/plant, leaf:stem ratio and chlorophyll content of leaves of fodder pearl millet was significantly influenced with application of increasing doses of nitrogen. The highest plant height (182.39 cm), number of tillers/plant (4.79), leaf: stem ratio (0.37) and chlorophyll content of leaves (1.49 mg/g) were recorded with maximum nitrogen level of 120 kg/ha being at par to lower level *i.e*. 90 kg/ha and registered statistically superior to preceding lower N doses at both cutting stages (Table 1). Number of leaves/plant (14.32) recorded maximum at 120 kg N/ha, which was significantly higher over all lower N levels and control. Nitrogen has essential functions in plant life *viz.,* its role in rapid multiplication of tissues and increase in amount of growth substances such as naturally occurring phytohormones, photosynthesis rate, increase level of auxin supply with higher level of nitrogen might have brought about a significant increase in plant height, and number of tillers per plant, number of leaves per plant, leaf: stem ratio and chlorophyll content of leaves in the present investigation. It was also reported that increase in plant height with nitrogen fertilizer was due to the fact that nitrogen promotes number of internodes and increase length of the internodes which results in progressive increase in plant height. Further, the increase in leaf to stem ratio with nitrogen application was probably due to the increase in number of leaves and leaf area under nitrogen treatments, producing more and heavy leaves. These results were in close conformity with the findings of earlier studies (Puri and Tiwana, 2005; Singh and Sumeriya, 2010; Meena *et al.,* 2012; Kumawat *et al.,* 2016).

Quality: Nitrogen free extract and total digestible nutrient were noted maximum with no nitrogen (0 kg/ha) and decreased significantly at higher N levels (120 kg/ha) in pearl millet. On the contrary, ether extract, crude fiber and ash contents were recorded to increase with increasing

Table 1. Effect of nitrogen and zinc levels on growth of forage pearl millet

Treatment	Plant height (cm)		Tillers/ plant (No.)		Leaves/ plant (No.)		Leaf: stem ratio		Chlorophyll content of leaves (mg/g)	
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Nitrogen levels (kg/ha)										
N_0	111.84	58.98	3.91	2.29	7.44	4.07	0.21	0.15	1.88	1.76
N_{30}	128.11	73.05	4.25	2.65	9.75	5.08	0.27	0.20	2.14	1.97
N_{60}	143.88	81.36	4.45	2.84	10.95	5.62	0.31	0.23	2.27	2.07
N_{90}	175.41	92.43	4.76	3.08	13.35	6.71	0.35	0.26	2.40	2.20
N_{120}	182.39	97.05	4.79	3.13	14.32	7.26	0.37	0.28	2.48	2.26
SEm ±	2.77	1.86	0.05	0.03	0.21	0.08	0.01	0.01	0.03	0.03
CD (P<0.05)	7.94	5.32	0.13	0.10	0.59	0.22	0.03	0.03	0.09	0.10
$ZnSO_4$ levels (kg/ha)										
Zn_0	138.72	77.38	4.34	2.71	10.27	5.16	0.26	0.19	2.08	1.91
Zn_{15}	145.11	78.21	4.36	2.76	10.75	5.37	0.29	0.21	2.19	2.02
Zn_{30}	154.26	82.66	4.47	2.86	11.73	5.80	0.32	0.24	2.31	2.13
Zn_{45}	155.21	84.05	4.56	2.88	11.89	6.67	0.33	0.25	2.36	2.15
SEm ±	2.48	1.66	0.04	0.03	0.18	0.07	0.01	0.01	0.03	0.03
CD (P<0.05)	7.10	4.76	0.12	0.09	0.53	0.20	0.03	0.02	0.08	0.09

Table 2. Effect of nitrogen and zinc levels on quality of forage pearl millet

Treatment	Crude fiber (%)		Ether extract (%)		Ash (%)		Nitrogen free extract (%)		Total digestible nutrient (%)	
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Nitrogen levels (kg/ha)										
N_0	27.99	28.75	2.06	1.99	10.79	10.12	52.56	53.02	60.26	60.63
N_{30}	28.13	28.89	2.13	2.03	11.00	10.32	50.86	51.41	60.07	60.42
N_{60}	29.18	29.97	2.16	2.10	11.42	10.71	48.55	49.11	59.65	60.06
N_{90}	30.33	31.14	2.18	2.11	11.62	10.91	46.80	47.39	59.40	59.80
N_{120}	30.28	31.08	2.20	2.13	11.68	10.95	46.59	47.20	59.37	59.78
SEm ±	0.88	0.90	0.04	0.07	0.35	0.37	0.78	0.81	0.23	0.26
CD (P<0.05)	NS	NS	0.10	NS	NS	NS	2.22	2.33	0.66	0.73
$ZnSO_4$ levels (kg/ha)										
Zn_0	28.40	29.17	2.10	2.00	10.90	10.30	50.65	51.15	60.08	60.39
Zn_{15}	29.05	29.83	2.14	2.04	11.10	10.45	49.72	50.22	59.92	60.25
Zn_{30}	29.31	30.10	2.16	2.11	11.40	10.75	48.87	49.33	59.68	60.06
Zn_{45}	29.97	30.77	2.18	2.12	11.80	10.90	47.04	47.80	59.31	59.85
SEm ±	0.79	0.80	0.03	0.07	0.32	0.33	0.69	0.73	0.21	0.23
CD (P<0.05)	NS	NS	NS	NS	NS	NS	1.99	2.08	0.59	NS

nitrogen levels up to 120 kg/ha which was at par to 90 kg/ ha, though statistically proved non-significant at all cutting stages except ether extract at first cut stage which improved significantly with higher N levels (Table 2). Further, increasing N fertilization in fodder pearl millet increased the availability of nitrogen in the rhizosphere, since nitrogen is main constituent of amino acids, it ultimately increased crude protein contents of plants. These results were in cognizance with the findings of Manohar *et al.* (1991), Shivran and Pareek (2001) and Saini (2012). The higher percentage of crude fat in plant receiving higher dose of nitrogen might be due to more chlorophyll of leaves. The higher amount of chloroplast and other pigments at early age of the plant might have also attributed to higher crude fat content at early stage. Deposition of structural carbohydrates in plant during later stages might be one of the reasons towards increase in fibre contents. Ayub *et al.* (2002) and Meena *et al.* (2012) also reported similar findings and were in close conformity with the present study. Nitrogen free extract was recorded maximum in control treatment which was significantly higher over 120, 90 and 60 kg N/ ha, but

Table 3. Effect of nitrogen and zinc levels on content and uptake of forage pearl millet

Treatment	Nitrogen content (%)		Zn content (ppm)		Crude protein (%)	
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Nitrogen levels (kg/ha)						
N_0	1.06	0.98	31.99	29.75	6.61	6.13
N_{30}	1.26	1.18	33.58	31.23	7.88	7.36
N_{60}	1.39	1.30	34.34	31.94	8.69	8.11
N_{90}	1.45	1.35	34.93	32.49	9.07	8.46
N_{120}	1.48	1.38	35.43	32.95	9.25	8.64
S.Em ±	0.03	0.02	1.03	0.96	0.19	0.12
CD (P<0.05)	0.07	0.06	2.96	2.75	0.54	0.36
$ZnSO_4$ levels (kg/ha)						
Zn_0	1.27	1.18	30.92	28.76	7.95	7.38
Zn_{15}	1.28	1.19	33.98	31.61	7.99	7.46
Zn_{30}	1.32	1.23	35.26	32.80	8.26	7.71
Zn_{45}	1.44	1.35	36.05	33.53	9.01	8.41
SEm ±	0.03	0.02	0.92	0.86	0.17	0.11
CD (P<0.05)	0.08	0.06	2.65	2.46	0.48	0.32

Treatment	Nitrogen uptake (kg/ha)			Crude protein yield (q/ha)		Zn uptake (g/ha)		
	1st cut	2nd cut	Total	1st cut	2nd cut	1st cut	2nd cut	Total
Nitrogen levels (kg/ha)								
N_0	21.27	15.19	36.46	1.33	0.95	68.42	73.83	142.25
N_{30}	30.30	22.72	53.02	1.89	1.42	102.08	86.30	188.38
N_{60}	38.59	30.03	68.62	2.41	1.88	133.91	90.35	224.26
N_{90}	48.05	38.49	86.54	3.00	2.41	169.80	99.98	269.79
N_{120}	49.68	40.76	90.44	3.11	2.55	177.96	104.39	282.36
S.Em ±	1.71	1.09	2.15	0.11	0.07	7.48	4.11	8.93
CD (P<0.05)	4.89	3.12	6.15	0.31	0.19	21.42	11.75	25.58
$ZnSO_4$ levels (kg/ha)								
Zn_0	29.72	22.86	52.59	1.86	1.43	92.72	75.90	168.61
Zn_{15}	34.22	26.41	60.62	2.14	1.65	117.60	86.84	204.44
Zn_{30}	40.76	32.21	72.97	2.55	2.01	145.56	95.30	240.86
Zn_{45}	45.61	36.27	81.88	2.85	2.27	165.86	105.86	271.72
SEm ±	1.53	0.97	1.93	0.10	0.06	6.69	3.67	7.99
CD (P<0.05)	4.37	2.79	5.50	0.27	0.17	19.16	10.51	22.88

it was found at par with 30 kg N/ha at the both cutting stage (Table 2). This might be attributed to the fact that nitrogen application at higher doses had significant effect on crude protein content, thereby reducing the proportion of carbohydrates. These results corroborated with the findings of Yadav *et al.* (1988), Manohar *et al.* (1991), Jakhar *et al.* (2003) and Saini (2012).

Nitrogen content and uptake: Application of increasing levels of nitrogen up to 120 kg/ha significantly increased the nitrogen content as well as total nitrogen uptake by pearl millet fodder (Table 3). Though, non-significant difference was noted between 60-90 and 90-120 kg/ha. This might be due to increased availability of nitrogen to plants resulted in vigorous vegetative and root growth leading to improved absorption of other nutrient from soil and hence, more concentration in plant. Moreover, nitrogen fertilization might increase the cation exchange capacity of roots and thus makes more efficient in absorbing other nutrient ions. The results obtained here were in close conformity with findings of Yadav *et al.* (1988) who also found increased Zn content of pearl millet fodder due to application of nitrogen. Also, improvement in photosynthetic efficiency of plants as evident from higher dry matter production by ground parts might have supplied adequate metabolites for root growth and its functional activity. Another reason for higher nitrogen content in plant might be due to increased activities of nitrate reductase.

$ZnSO_4$ levels

Growth: Increasing dose of $ZnSO_4$ from 0 to 45 kg/ha improved plant height, number of tillers/plant, number of leaves/plant, leaf: stem ratio and chlorophyll content of leaves at both cutting stages. Zinc sulphate @ 45 kg/ha was found at par with 30 kg/ha recorded the maximum values of above mentioned growth parameters and showed statistically superiority over 15 kg zinc sulphate/ha dose and control (Table 1). The beneficial effect of zinc in plant was due to increased auxin concentration and its stimulating effect on most of the physiological and metabolic processes together with more available nitrogen, augmented the production of photosynthates and their translocation to different parts including leaves of fodder pearl millet, which increased the chlorophyll content in the leaves. The results of present investigation were in close conformity with findings of Malikwal *et al.* (1989) and Verma *et al.* (2005).

Quality: Significantly higher crude protein yield was obtained when the crop was fertilized with 45 kg $ZnSO_4$/ha in comparison to control and lower zinc application at both cutting stage (Table 2). This was probably due to the fact that zinc also increases the cation exchange capacity of the roots which in turn enhances the absorption of essential element especially nitrogen which was responsible for higher crude protein content in fodder pearl millet. No zinc application significantly recorded the highest nitrogen free extract (NFE) compared to control at both cutting stages. The TDN content in fodder pearl millet was statistically unaffected by zinc application (Table 2). The protein content and zinc concentration of pearl millet plant were improved by increasing zinc fertilizer doses during both cutting stages. This clearly indicated that increasing zinc level in root zone ensured more availability of nutrients particularly N and Zn which in turn increased absorption by plant and thereby increasing nutrient status at cellular level. Zinc is required as structural and catalytic components of protein or amino acids. These results were in conformity with the findings of Manohar *et al.* (1991), Jahiruddin *et al*. (2001) and Dhadich and Gupta (2005).

Zinc content and uptake: Application of zinc sulphate up to 30 kg/ha had non-significant effect on Zn content and uptake in pearl millet at the both cutting stages. Further zinc sulphate by 45 kg/ha significantly improved quality parameters compared to control. Thus the addition $ZnSO_4$ from 0 to 45 kg/ha at sowing time seems to have enriched Zn status of the soil rhizosphere which led to its higher extraction by plants for their growth and development. This was also well evidenced from the nutrient analysis where, basal application of $ZnSO_4$ tended to improve not only Zn status but also had synergistic effect on N content of the plant parts (Table 3). Thus greater availability of both the nutrients as per requirement for growth of individual plant parts seems to have increased accumulation of dry matter. Similar results were also observed earlier by Ashoka *et al.* (2008) and Mohan *et al.* (2015).

Conclusion

The findings of the present study indicated that application of nitrogen 90 kg/ha and zinc sulphate 30 kg/ha was suitable for growth and quality parameters of fodder pearl millet in hyper arid region of Rajasthan.

Acknowledgement

The authors thank the Department of Agronomy at College of Agriculture, SKRAU, Bikaner and express sincere gratitude to Dr. S.R. Bhunia for his valuable guidance, incessant encouragement and constructive suggestions.

References

AOAC. 1990. *Official Methods of Analysis, 15th edition.* Association of Official Analytical Chemists, Wahington, DC.

Alloway, B.J. 2008. *Zinc in Soil and Crop Nutrition*. International Zinc Association and International Fertilizer Association Brussels, Belgium and Paris, France.

Ashoka, P., M. Mudalagiriyappa., B.T. Pujari, P.S. Hugar and B.K. Desai. 2008. Effect of micronutrients with or without organic manures on yield of baby corn (*Zea mays* L.) chickpea (*Cicer arietinum* L.) sequence. *Karnataka Journal of Agricultural Sciences* 21: 485-487.

Ayub, M., M.A. Nadeem, A. Tanveer, M. Tahir and R.M.A. Khan. 2007. Interactive effect of different nitrogen levels and seeding rates on fodder yield and quality of pearl millet. *Pakistan Journal of Agricultural Science* 44: 592–596.

Ayub, M., M.A. Nadeem, A. Tanveer and A. Husnain. 2002. Effect of different levels of nitrogen and harvesting times on growth, yield and quality of sorghum fodder. *Asian Journal of Plant Sciences* 4: 304-307.

Cecelia, L. F., S. L. Amigot, M. Gaggiotti, L. A. Rumero and J. C. Basilico. 2007. *Global Science, Forage Quality: Techniques for Testing.* pp. 123.

Dadhich, L.K. and A.K. Gupta. 2005. Effect of sulfur, zinc and planting pattern on yield and quality of fodder pearl millet. *Indian Journal of Agricultural Sciences* 75: 49-51.

Gascho, G.J., R.S.C. Menezes, W.W. Hanna, R.K. Hubbed and J.P. Wilson. 1995. Nutrient requirements of pearl millet. In: Proceedings of *National Symposium on Grain Pearl Millet, 1st Tifton,* GA. University of Georgia, Tifton. pp. 92-97.

Gomez, K. A. and A. A. Gomez. 1976. *Statistical Procedures for Agricultural Research.* 2nd edn. John Willey and Sons Inc. New York, USA.

Hiscox, J.D. and G.F. Israelstem. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany* 57: 1332-1334.

Jahiruddin, M., H. Harada, T. Hatanaka and Y. Sunaga. 2001. Adding boron and zinc to soil for improvement of fodder value of soybean and corn. *Communications in Soil Science and Plant Analysis* 32: 2943-51.

Jakhar, S., H.S. Sharma and S.R. Kantwa. 2003. Effect of nitrogen and sulphur on quality and nutrient content of fodder pearl millet [*Pennisetum glaucum* (L.) R.Br. emend stuntz]. *Annals of Agricultural Research* 24: 169–71.

Jones, D.B. 1931. Factors for converting percentages of nitrogen in foods and feeds into percentages of protein. *USDA Circular No.* 183: 1- 21.

Kumawat, S.M., Mohd, Arif, S.S. Shekhawat and S.R. Kantwa. 2016. Effect of nitrogen and cutting management on growth, yield and quality of fodder pearl millet (*Pennisetum glaucum*) cultivars. *Range Management and Agroforestry* 37: 207-213.

Malikwal, G. L., R. R. Patel, V.V. Sonani and G.A. Sasani. 1989. Effect of nitrogen, phosphorus and zinc on the yield and water use by pearl millet under rainfed conditions. *Indian Journal of Agricultural Research* 23: 15-21.

Manohar, S.S., G.D. Singh and P.S. Rathore. 1991. Effect of nitrogen phosphorus and zinc levels on quality parameters of fodder pearl millet (*Pennisetum glaucum*). *Indian Journal of Agricultural Sciences* 36: 448–450.

Meena, S.N., K.K. Jain, P. Dasharath and P. Ram. 2012. Effect of nitrogen on growth, yield and quality of fodder pearl millet (*Pennisetum glaucum*) cultivars under irrigated condition of north-western Rajasthan. *Annals of Agricultural Research* 3: 183-188.

Mohan, S., M. Singh and R. Kumar. 2015. Effect of nitrogen, phosphorus and zinc fertilization on yield and quality of *kharif* fodder - A review. *Agricultural Reviews* 36: 218-226.

Puri, K.P and U.S. Tiwana. 2005. Response of pearl millet varieties to nitrogen levels under irrigated conditions. *Range Management and Agroforestry* 26: 124–126.

Saini, A. 2012. Forage quality of sorghum (*Sorghum bicolor*) as influenced by irrigation, nitrogen levels and harvesting stage. *Indian Journal of Agricultural Science* 3: 67-72.

Shivran, D.E. and R.K. Pareek. 2001. Effect of nitrogen, phosphorus and cropping system on physiological parameters yield and quality of pearl millet *(Pennisetum americanum)* fodder. *Forage Research* 27: 29-33.

Singh, M.V. 2009. Micronutrient nutritional problems in soils of India and improvement for human and animal health. *Indian Journal of Fertilizers* 5: 19-26.

Singh, P. and H.K. Sumeriya. 2010. Response of growth and forage yield of pearl millet (*Pennisetum glaucum*) to nitrogen fertilization rates and cutting height. *Annals of Agricultural Research* 5: 153–162.

Singh, R.K., D. Chakraborty, R.N. Garg, P.K. Sharma and U.C. Sharma. 2010. Effect of different water regimes and nitrogen application on growth, yield, water use and nitrogen uptake by pearl millet (*Pennisetum glaucum*). *Indian Journal of Agricultural Sciences* 80: 213-216.

Verma, S.S., N. Singh, Y.P. Joshi and Deorari. 2005. Effect of N and Zn on growth characters, herbage yield, nutrient uptake and quality of fodder for sorghum. *Indian Journal of Agricultural Sciences* 50: 167-169.

Yadav, J.P., G. D. Singh and G. L. Keshwa. 1988. Effect of different nitrogenous fertilizers and levels of zinc on nutrient uptake and yield of pearl millet. *Indian Journal of Agricultural Sciences* 34: 428-430.