9th Intl. Plant Nutrition Colloquium Warwick Univ, Coventry, UK. 22-27 Aug 1982

CP 97

1749

NITROGEN UPTAKE AND UTILIZATION BY PEARL MILLET [*Pennisetum americanum* (L.) Leeke]

G. ALAGARSWAMY, F.R. BIDINGER

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ABSTRACT

Twenty pearl millet cultivars grown during two rainy seasons over two fertility levels were examined for dry matter production, grain yield and nitrogen related physiological traits. Differences between the two fertility levels were substantial for all characters studied. Cultivars did not differ significantly in their nitrogen uptake but did differ in their ability to use nitrogen. The cultivar x fertility interactions for grain yield and efficiency of grain production per unit of N uptake indicated that response to fertility is a matter of responsiveness in grain production efficiency. Genotypic variation in the efficiency of N utilization rather than in uptake was responsible for variation in growth and grain yield. The usefulness of such genotypic variation in crop improvement is discussed.

INTRODUCTION

There is an increasing worldwide interest in altering crops genetically to obtain higher grain yields under mineral stress problem soils. Agricultural researchers are consciously directing studies towards a low cost genetic approach to alleviate mineral stress related problems (Fox 1978, Chichester 1981, Clark 1981). For an important crop of the Semi-Arid Tropics (SAT) such as pearl millet [*Pennisetum americanum* (L.) Leeke] a similar approach by crop scientists is very appropriate since infertile soils are one of the common features of African and Asian millet growing areas. Jones (1973) reported that for 295 well drained West African savanna soils, the mean nitrogen (N) content of the top soil was 0.05 per cent with a lower limit of 0.008 per cent; these soils are also low in organic matter. Similarly the Alfisols (Luvisols) of penninsular India are characterised by N and phosphorus deficiency, coupled with low organic matter (Swindale 1982). About 95 per cent of the world's pearl millet is being produced from such soils, generally without the addition of fertilizer N. The millet crop production relies to a large extent on the mineralized N from organic residues that is available primarily as an initial flush at the beginning of the rains (Blondel 1971). We assume under such conditions both the ability to forage for this N as it is leached down the soil profile and the ability to efficiently use limited amounts of N are important. N available from rhizosphere N fixation may also make an important contribution (Dart & Wani 1982). The search for cultivars with both characteristics needs to be intensified. In this paper, we have examined i) the genetic variation in pearl millet for N uptake, and ii) the relationship of N uptake and efficiency to dry matter production and grain yield.

Submitted as C.P. no. 97 by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

MATERIALS AND METHODS

Twenty pearl millet cultivars were grown in Alfisol during 1978 and 1980 rainy seasons at ICRISAT Center near Hyderabad, India (lat. 17N). Available soil N was not measured in 1978; in 1980 there was approximately 50 Kg/ha of NO_3 N accumulated in the profile (120 cm) at the beginning of the rainy season. Nearly 50 per cent of this quantity was in the top 20 cm layer. Two fertility treatments, i) high fertility (HF) 100 Kg N and 25 Kg P, and ii) low fertility (LF) 20 Kg N and 9 Kg P/ha, were created by application of inorganic fertilizers. Under these experimental conditions, N was assumed to be the most limiting nutrient in LF and to be in adequate supply in HF. Each fertility treatment was replicated four times. Cultivars were sown as subplots within the main plot fertility treatments in 4 rows of 0.75 x 4 m (1978) or 0.75 x 9 m (1980). Plant population was maintained at 133,000/ha.

At flowering and maturity stages, plants in quadrats of 1.2 m^2 were cut at ground level, plant parts separated, dried at 80 °C for 72 hours, weighed, and ground to pass through a 20 mesh screen. N concentration in the dry matter was estimated by the standard micro-Kjeldahl method. Grain yield was determined from 2.5 m^2 in 1978 and in 1980 from 9 m^2. Two efficiency ratios, 1) NE_{DM}-total dry matter per unit of total N taken up, and 2) NE_G-grain yield per unit of total N taken up were calculated.

RESULTS

Growth, nitrogen uptake and utilization

Differences between the two fertility levels were substantial for all characters studied, ranging from more than 200 per cent for N uptake to approximately 70 per cent in total dry matter production (see Table 1).

TABLE 1

Descriptive statistics for crop growth, grain yield and nitrogen uptake parameters for 20 pearl millet cultivars. Values are based on observations from four replications.

Character	Year	LF		HF	
		Mean	Range	Mean	Range
Total DW g m^{-2}	1978	429	284 - 555	914	666 - 1073
	1980	647	452 - 798	831	709 - 995
Grain DW g m^{-2}	1978	110	67 - 149	261	178 - 321
	1980	162	86 - 215	251	198 - 302
Total N content g m^{-2}	1978	4.2	2.8 - 5.9	13.1	11.2 - 15.1
	1980	4.8	4.0 - 5.6	7.9	6.7 - 9.6
NE_{DM}	1978	107	94 - 124	71	59 - 82
	1980	139	112 - 180	107	89 - 131
NE_G	1978	28	17 - 36	20	15 - 25
	1980	34	19 - 41	33	22 - 41

Grain yields in the HF treatment were similar to the average dryland experiment station trials (2.5 t/ha) and LF yields similar to 1.3 t/ha recorded in the adaptation trials on farmers' fields (Singh, G. & Naidu, E.V., unpublished work, presented at All India Coordinated Millet

Improvement Project annual meeting, Coimbatore, India, 26-29 April 1982). Total crop growth under LF was less in 1978 than in 1980, probably due to excessively wet conditions in 1978, in which 1007 mm rainfall was received in the June-September cropping period compared to 727 mm in the same period in 1980. Grain yields, however, were not significantly different between years.

Cultivars did not differ significantly in the N uptake, but did differ both for total dry matter and grain yields produced. These differences were explained by significant differences among cultivars in NE_{DM} and NE_G (Table 2). Cultivar x fertility interactions were not significant for N uptake, total dry matter or NE_{DM}, but were for both grain yield and NE_G. This suggests that response to fertility was primarily a matter of responsiveness in NE_G rather than in either N uptake ability or NE_{DM}.

TABLE 2

F ratios for year, fertility and cultivar for dry weight, grain yield and N uptake and use efficiency.

Source	df	Dry wt.	Grain yield	Total N uptake	NE_{DM}	NE_G
Year (Y)	1	8.3*	4.1^{NS}	47**	76**	159**
Fertility (F)	1	207**	139**	315**	73**	35**
F x Y	1	42**	9.1*	73**	0.3^{NS}	16**
Cultivar (C)	19	4.4**	9.6**	1.3^{NS}	3.7**	8.7**
F x C	19	1.1^{NS}	2.7**	1.2^{NS}	0.8^{NS}	2.2**
Y x C	19	1.8*	2.9**	1.5^{NS}	3.9**	3.3**
F x Y x C	19	1.0^{NS}	1.0^{NS}	0.8^{NS}	1.2^{NS}	0.5^{NS}
Mean		*705*	*196*	*7.48*	*106*	*29*
CV%		*17*	*17*	*22*	*13*	*16*

*, ** significant at 0.05 and 0.01 levels, respectively
NS Not significant

Year x cultivar interactions were significant for all parameters excepting N uptake. The F ratios for cultivar x year interactions were generally larger than those for cultivar x fertility interactions (Table 2). Year x fertility x cultivar interactions were not significant for any of the parameters, indicating that while cultivar performance was affected by year differences, cultivar response to fertility did not differ between years.

Efficiency *vs* uptake

The larger cultivar differences for efficiency of N utilization than for N uptake suggested that the former rather than the latter was related to differences in cultivar yielding ability. This conclusion was tested by using N uptake and efficiency (in logarithmic form) as independent variables in regression models of total crop dry weight and grain yield, with the object of comparing the relative contributions of take and efficiency. Results support the conclusion that the variation in efficiency of use of N is primarily responsible for variation in grain yields, at both high and low levels of fertility (accounting for 79 per cent of the variation in grain yield) (Table 3). For total crop dry matter production however, variation in both uptake and efficiency contributed approximately in equal measure.

TABLE 3

Per cent total sum of squares (SS) for total dry weight and grain yield accounted for by NE and N uptake (all variables in logarithmic form; regression model $Y = a + b_1x_1 + b_2x_2$)

Source		% total SS due to	
		N uptake (x_1)	Efficiency of use NE_{DM} or NE_G (x_2)
Total dry weight			
LF	1978	82	16
	1980	37	62
HF	1978	41	57
	1980	25	74
	Mean	*46*	*52*
Grain yield			
LF	1978	27	70
	1980	17	82
HF	1978	27	73
	1980	8	92
	Mean	*20*	*79*

DISCUSSION

Cultivar differences in grain yield and cultivar x fertility interactions were expected in the present experiment as it contained a range of cultivars, from improved landraces to high yielding F_1 hybrids. A part of these interactions were certainly due to the somewhat greater responsiveness of the elite materials, in terms of grain yield as compared to total dry matter, to higher levels of fertility. This is consistent with the finding that there were no cultivar x fertility interactions for total dry matter or NE_{DM}, but there were interactions for grain yield and NE_G.

Cultivar differences in efficiency of N use rather than total N uptake have been reported in other crops. O'Sullivan et al (1974) observed that for the same amount of N in the plant, N efficient tomato lines produced an average of 40 per cent more dry weight than did inefficient plants. Similarly, at low levels of nitrate in solution culture, at similar uptake levels, one plum clone produced 39 per cent dry matter per mg absorbed N than the other (Therios et al 1979). Differences in utilization of nutrients between clones were more generally found at low levels of available nutrients rather than at sufficient levels (Therios et al 1979). Similarly genetic variation in efficiency parameters in the present experiments were of higher magnitude under LF compared to HF (Table 1).

The existence of considerable variability for N use efficiency, especially for grain yield and the high degree of correlation between NE_G and grain yield ($r = 0.75^{**}$, $p < .01$) suggest that direct selection for N efficiency may have value in improvement of yielding ability under low fertility conditions. It is worth investigating whether the genotypic variations in NE_G are heritable, and if so whether it is possible to exploit such variations in crop improvement program. Selections for efficiency at low levels of N could be carried out in controlled conditions either in soil or in solution culture (such as continuous flow culture, Asher et al 1965), once it was established that these selection procedures produce plants that are more efficient under field conditions.

ACKNOWLEDGEMENT

We acknowledge the assistance of Mr. D.S. Raju and Mr. G.D. Prasada Rao in field work and data analysis. We are also grateful to our colleagues who critically reviewed this paper.

REFERENCES

Asher, C.J.; Ozanne, P.G.; Loneragan, J.F. (1965) A method for controlling the ionic environment of plant roots. Soil Science 100, 149-156.

Blondel, D. (1971) Contribution a la Connaissance de la dynamique de l'azote mineral en sol sableux (dior) au Senegal. L'Agronomie Tropicale 26, 1303-1333.

Chichester, F.W. (1981) Selecting for nutrient use efficiency within forage grass species : I. Development of a screening system. Journal of Plant Nutrition 4, 231-246.

Clark, R.B. (1981) Plant response to mineral element toxicity and deficiency. In Lewis, C.P; Christiansen, M.N. (Eds.) Breeding plants for marginal environments. John Wiley Sons, Inc. New York, N.Y. p. 74-196.

Dart, P.J.; Wani, S.P. (1982) Non-symbiotic nitrogen fixation and soil fertility. Transactions of the 12th International Congress of Soil Science, New Delhi, India, 8-16 February.

Fox, R.H. (1978) Selection for phosphorus efficiency in corn. Communications in Soil Science and Plant Analysis 9, 13-17.

Jones, M.J. (1973) The organic matter content of the savanna soils of West Africa. Journal of Soil Science 24, 42-53.

O'Sullivan, J.; Gabelman, W.H.; Gerloff, G.C. (1974) Variations in efficiency of nitrogen utilization in tomatoes (*Lycopersicon esculentum* Mill) grown under nitrogen stress. Journal of American Society of Horticultural Sciences 99, 543-547.

Swindale, L.D. (1982) Distribution and use of arable soils in the Semi-Arid Tropics. Transactions of the 12th International Congress of Soil Science, New Delhi, India, 8-16 February.

Therios, I.N.; Weinbaum, S.A.; Carlson, R.M. (1979) Nitrate uptake effectiveness and utilization efficiency of two plum clones. Physiologia Plantarum 47, 73-76.