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Mini Review

Correlation of the Foliar Nitrogen Content with Yield and Grain Protein Accumulation in Pearl Millet

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Mini-Review

Agriculture needs to feed the quick increase in human population, especially under climate change, with a decrease in annual rainfall and an increase in air temperatures in many agricultural regions. These effects are more significant in marginal areas for agriculture than in areas with high quality for agriculture, which are submitted to environmental stresses and where population growth is higher [1]. New strategies are thus required to increase agricultural food production systems, such as developing new farming systems and using undervalued crops that are more tolerant to stress [1], especially for small family farmers in these marginal areas for agriculture. Pearl millet [*Pennisetum glaucum* (L) R. Brown is a major staple food crop in the drier parts of the old world, like the Sahelian region of Africa and India. It is the sixth essential cereal worldwide, a staple food for around 90 million people in these regions [2]. Pearl millet can be cultivated in a low-input agro-system, without costly agronomic inputs during its 90 days cycle, producing higher biomass with good crude protein content (around 15%) for forage than maize or sorghum [3]. The grain of pearl millet has approximately 30% more protein than corn. In addition, the great advantage of using pearl millet for grain production is its low-input cultivation, without fertilization or irrigation, due to its relative adaptation to low rainfall conditions and the soil's poor nutrients. Pearl millet is one of the world's most drought and high-temperature tolerant crops, primarily due to its profound root system, with more than two meters deep [3]. In the past, plant breeding programs were based on plant response to fertilization, irrigation, and other agricultural high inputs to increase plant yield. However, after the oil crisis in 1970, the new breeding programs' objectives were to adapt the plant to the environment, developing low-input and sustainable production systems, especially for the semiarid tropical regions. For this reason, the improvement of nitrogen (N) use efficiency (NUE) by plants needs to be one of the targets of plant breeding programs due to the actual fertilization cost.

For this purpose, pearl millet genotypes were selected using the leaf N and grain N content at flowering and grain maturity stages [3]. Some traits showed high heritability and were correlated with yield (Table 1). The following characteristics were used: second Leaf N Content At Flowering (LNCF), second Leaf N Content At Harvest (LNCH), stover N content at harvest (SNCH), Grain N Content (GNC), Stover (dry weight) Yield At Harvest (SYH), and Grain Yield (GY). The second leaf's N content was evaluated rather than the first leaf because the apical first leaf is tiny in pearl millet and is not a good source of photoassimilates for the grain. Among the significant residual correlation (re) obtained, with some remarkable features as for the LNCF trait, which was not significant among families but was positively correlated with SYH, GY, SNA, GNA, BNA, and NME (Table 1). Consequently, the second leaf's N content influences all the latter traits, especially stover and grain yield. In addition, the heritability (h2m) for the LNCH and SNCH were high (0.85 and 0.70, respectively), showing a great possibility of gain on selection for these traits. In this study, SYH and GY were suggested to be the primary traits to select pearl millet genotypes for stover and grain production under a limited N supply, followed by the LNCH, SNCH, and GNC traits, improving the stover and grain quality. In addition, Stover crude protein content (N tissue content. 6.25) of ENA 2 was around 6.77%, very close to 7.0%, considered the minimum level required for cattle maintenance [3].

Therefore, two new pearl millet cultivars were selected in the Federal Rural University of Rio de Janeiro (UFRRJ), ENA 1 (2002) and ENA 2 (2009), registered in the Department of Agriculture of Brazil (RNC/MARA) under the numbers 04291 and 25557. There are Indian-derived millets in Brazil, such as BRS1501 (Registered by the Brazilian Enterprise of Agriculture, EMBRAPA), and African-derived, such as ENA1 and ENA2, which are available and cultivated, among others. Therefore, an experiment was done to evaluate the biomass and quality grain traits for these three millet cultivars, to propose recommendations for harvest at flowering or maturity, as well as the best agricultural uses for them, and to make recommendations for plant breeding. The biomass and grain traits proposed for evaluation were biomass at flowering and maturity and the contents of storage protein fractions in grain. The cycle of the cultivars was between 90 and 104 days after sowing. The shoot dry weight at flowering, which can be used for no-till agriculture or forage, and at maturity, the shoot fresh and dry weights were all higher for the African genotype. Mainly ENA 2, which had the highest weight at maturity to be used as stover for livestock, was higher for the two African genotypes than for the Indian genotype (Table 2).

Table 1: Residual correlations (re) between traits of 36 families: LNCF, second leaf N content at flowering; LNCH, second leaf N content at harvest; GNC, grain N content; SNCH, Stover N Content At Harvest; SYH, Stover Yield At Harvest; GY, Grain Yield; SNA, Stover N Acquisition; GNA, Grain N Acquisition; BNA, Biomass N Acquisition; NUES, N Use Efficiency For Stover Production; NUEG, N Use Efficiency For Grain Production; HIN, Harvest Index For N; HI, Harvest Index.

	LNCH	GNC	SNCH	SYH	GY	SNA	GNA	BNA	NME	NUES	NUEG	HIN	HI
LCNF	ns	ns	ns	0.359*	0.409*	0.383*	0.410*	0.431**	0.909**	ns	ns	ns	ns
LCNH		0.325*	0.352*	ns	ns	0.364*	0.367*	0.374*	-0.413*	ns	ns	ns	ns
GNC			ns	ns	ns	0.340*	0.631**	0.543**	ns	-0.832**	-0.675**	0.330*	ns
SNCH				ns	ns	0.446**	ns	0.382*	ns	-0.591**	-0.464**	ns	ns
SYH					0.610**	0.854**	0.669**	0.813**	ns	Ns	-0.454**	ns	-0.453**
GY						0.696**	0.921**	0.889**	ns	-0.367*	ns	0.341*	ns
SNA							0.703**	0.904**	ns	ns	-0.595**	ns	ns
GNA								0.940**	ns	-0.426**	-0.329*	ns	ns
BNA									ns	ns	-0.484**	ns	ns
NME										ns	ns	ns	ns
NUES											ns		ns
NUEG												0.454**	0.580**
HI N													0.725**

ns,*,** no significant and significant differences among families at 5% and 1% of the t-test, respectively.

Table 2: Fresh and dry weight at flowering and maturation (g.plant^{-1}) and final grain yield (g.plant^{-1}) in the three pearl millet cultivars.

Cultivars	Fresh weight	Dry weight
	Flowering stage	
ENA 1	538,33 ^{ns}	123,33 a
ENA 2	538,33 ^{ns}	130,00 a
BRS 1501	411,67 ^{ns}	96,67 b
Maturity stage		
ENA 1	273,33 b	80,00 b
ENA 2	360,00 a	98,33 a
BRS 1501	198,33 c	56,66 c
Final Yield		
ENA 1		49,0 ab
ENA 2		61,4 a
BRS 1501		54,3 ab

Means followed by the same letter did not differ according to the LSD test (α = 0.05).

The morphological traits evaluated in this study (Tables 1 and 2) indicated that the African genotypes ENA1 and ENA 2 are better than the Indian genotype BRS1501 for no-till farming or to produce forage with 15 % of crude protein at flowering and 6.77% at harvest [3] to produce stover. Interestingly, the cultivar preferably recommended for grain production for manufacturing chicken feed, based on grain crude protein content, was the Indian genotype BRS1501 and was superior in the amount of crude grain protein, CP (Table 3).

Table 3: Grain storage protein fractions (% of weight) and crude protein content (CP, g kg^{-1}) of three pearl millet cultivars.

Cultivar	Globulins	Albumins	Prolamins	Glutelins	CP*
BRS 1501	43.9 b	17.1 a	25.6 a	13.4 b	17,6 a
ENA 1	48.2 a	10.7 b	21.4 b	19.7 a	11,4 b
ENA 2	48.1 a	11.5 b	21.2 b	19.2 a	12,0 b

Means followed by the same letter did not differ according to the LSD test (α = 0.05). * Total grain N x 6.25.

Whereas the cultivars of preference for biomass at flowering and harvest (Table 2), ENA1 and ENA 2, produced quality grains lower than BRS1501 for grain protein content (Table 3). However, among grain proteins, globulins contain up to 52% of essential amino acids, albumins contain up to 44%, glutelins contain around 30%, and prolamins contain up to 22% [4]. The high grain crude protein content of the BRS 1501 was associated with high albumins and prolamins, while the African genotypes, ENA 1 and ENA 2, had a higher globulin content, which is the grain protein richer in essential amino acids (Table 3). Based on the results, BRS1501 can be recommended for grain production since it exhibited higher content of crude grain protein than ENA1 and ENA2, which were indicated for biomass production at flowering or maturity.

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