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Emergence and Growth Characteristics of Sorghum and Pearl Millet Intercropped with French Beans after PEG-based Seed Priming under Greenhouse and Phytotron Conditions

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1 Introduction

Mixed cropping is a traditional practice in many parts of Africa, Asia and Latin America; it is also attracting interest in some temperate regions with warm climates such as Australia and the United States (Ofori and Stern, 1987). This may be due to some of the established and speculated advantages of intercropping systems that have become apparent over the years (PEARCE AND EDMONDSON, 1982; PETERSON, 1994; SENARATNE, *et al.*, 1995). The semi-arid tropics are characterized by a dry season of between six and nine months and by annual rainfall of 500-1000 mm (JAHNCKE, 1982). The growing season is short and rainfall varies considerably and unpredictably both within and between years, thereby hampering emergence and subsequent establishment of crops. Both sorghum and pearl millet, as main crops, have been intercropped with legumes in attempts to improve overall production and yield under such conditions (WANI, *et al.*, 1994; KHISTARIA AND SADARIA, 1995).

Preliminary investigations on priming of sorghum (AL-MUDARIS AND JUTZI, 1997A) and pearl millet (AL-MUDARIS AND JUTZI, 1997B) seeds have shown gains in germination and early seedling growth under limited moisture conditions when compared to the growth of unprimed controls. The practical value of priming over a wide range of conditions including mixed cropping, therefore, needs to be explored since, under many conditions, both crops are seldom planted alone but rather intercropped. This present study places emphasis on ascertaining whether priming with polyethylene glycol (PEG) affects stand establishment of sorghum and pearl millet intercropped with French beans and whether the osmotic effects of PEG (KANTAR, *et al.*, 1996) can be further enhanced by a mixture of salts and/or growth regulators.

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2 Materials and Methods

2.1 Intercropping with French beans after PEG-priming

Five priming treatments were applied to sorghum (*Sorghum bicolor* L. Moench) ICSV 745 and pearl millet (*Pennisetum glaucum* L. R. Br.) ICMH 451 seeds obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. These included PEG (molecular weight 10.000, Fluka Chemie AG, Germany) solutions of 100, 115, 130 and 145g/l yielding osmotic potentials of -2.2, -3.0, -4.0 and -4.8 bar, respectively. A dry, untreated control was also included. Seeds were soaked in the priming solutions at 20°C in the dark for 3 days. After retrieval, seeds were washed 3 times in distilled water and surface dried by exposure to an air flow at 25°C for 60 min. French beans (*Phaseolus vulgaris* L.) var. "Blue Peter" of South African origin were obtained from the seed collection of the tropical greenhouse at the Faculty of Agriculture, Witzenhausen, after storage at ambient conditions for 12 months. Experiments were conducted in a greenhouse in 2.5 l plastic pots filled with 2 kg of sieved sand. Ten sorghum or pearl millet seeds were either sown alone or in combination with 5 bean seeds. Each pot was irrigated with 150 ml of water on the day of sowing and 100 ml every 10 days thereafter. Temperature in the greenhouse ranged from 17 to 20°C and RH from 70 to 75 %. Pots were arranged on tables with supplementary irradiation being supplied by 4 yellow halogen lamps hanging 130 cm above table level at an intensity ranging from 20 to 22 Klux for 12 hours a day. Treatments were replicated 6 times and arranged in a randomized complete block design. Seeds were scored for plumule emergence at 24 hour intervals for 10 days and from this data the final germination percentage (FGP, %), mean germination time (MGT, ORCHARD, 1977), and coefficient of velocity of germination (CVG, JONES AND SANDERS, 1987) were calculated. Thirty days after sowing, shoots were harvested and dried in an oven at 80°C to a constant weight and, after cooling, their dry weights were recorded (DWS). Root weight analysis was not included because of inaccuracies in determining weights owing to sand residues. Analysis of variance was used to test for priming (dry control vs. 4 priming treatments), genotype (sorghum vs. pearl millet) and intercropping (intercropped vs. monocropped) effects as well as their interactions on arsin transformed germination percentages. Untransformed data are shown in tables for simplicity.

2.2 Enhancement of PEG with Growth Regulator and Salt Additives

To simulate natural daily variations in temperature, relative humidity and light, this experiment was conducted in a 18 m^3 walk-in phytotron with computer-aided environmental control (Heraeus-Voetsch, Germany). Photosynthetically active radiation was provided by a set of metal halide and low pressure sodium lamps generating approximately 33 klux at plant height.

The course of temperature, relative humidity and light activation during a 24 hour cycle are shown in Table 1. The course was developed after consideration of ambient conditions in a typical situation in the field. Six priming treatments including a dry control (hereafter termed T_1) were tested. The base treatment was a 3-day soak in a

130g PEG/l solution with a measured osmotic potential of -4.0 bar at 20°C (T_2). Additions of salts or growth regulators to this base treatment aimed at verifying whether the osmotic effect of priming with PEG could be enhanced by growth regulators/conditioners or other osmotically active agents based on previous work (AL-MUDARIS AND JUTZI, unpublished data). Seeds of M35-1, ICSV 112 and Barmer sorghum and millet varieties, respectively, were treated either as indicated above (T_1 and T_2) or in a PEG solution plus 200 mg/l of gibberrelic acid 3 (T_3), PEG + 7.5g/l urea fertilizer (T_4), PEG + 10g/l sucrose (T_5), PEG + 10g/l NaCl (T_6) or PEG + 25g/l ascorbic acid (T_7). After treatment seeds were washed three times in distilled water, surface dried as in the previous experiment, and sown in batches of 20 in 0.25 l polythene pots. Treatments were replicated 4 times and arranged in a randomized complete block design. Pots contained 412g of unsieved sand and were irrigated with 50 ml of water on the day of sowing. Thereafter, pots were scored for germination and weighed daily. A pot would be re-irrigated to its original weight if it had lost 40g (i.e. 40 ml of the designated 50 ml ration) in weight. Germination counts up to the 10^{th} day were used to calculate FGP, MGT and CVG.

Table 1: The course of temperature, relative humidity and light activation in the phytotron during a 24 hour cycle

Time	Temperature (°C)	Relative Humidity (%)	Light (33 Klux)
24.00-05.00 hours	15	65	Absent
06.00-08.00 hours	15	65	Activated
09.00-12.00 hours	25	55	Activated
13.00-19.00 hours	40	40	Activated
20.00-21.00 hours	25	55	Activated
22.00-23.00 hours	25	55	Absent

Two weeks after sowing, the first of two serial harvests was undertaken. Shoots were cut at the crown area, their lengths measured (SL_{14}), dried in a forced-air oven at 80°C for 3 days and weighed (DWS_{14}). The second harvest took place a week later (21 days after sowing). Here plants were uprooted and separated into shoots and roots. Roots were washed in a 3-stage process to remove sand particles, their length measured (Root length, RL_{21}) and dried. The same was done to shoots (SL_{21}). The dry weights of shoots (DWS_{21}) and roots (DWR_{21}) were taken and from them the shoot:root ratio (SRR) calculated by dividing the DWS_{21} by the DWR_{21}. The effects of single factors were tested and their mutual interactions evaluated statistically. An analysis of variance was carried out on all data after arsine transformation of the FGP. All data were analyzed by the General Linear Model subroutine of the SAS® package. Means comparison was done on the basis of Duncan's Multiple Range Test at the 5 % level of probability.

Table 2: Interactive effects of PEG concentration, genotype and intercropping on germination and growth characteristics of sorghum and pearl millet seedlings 30 days after sowing

PEG (g/l)	Genotype	Inter-cropping [1]	FGP[2] (%)	MGT[3] (day)	CVG[4]	DWS[5] (mg)
0	ICSV 745	I	73.3 cde	4.8 bc	20.6 bcde	15.6a
		M	80.0 cde	6.0 a	16.7 e	17.1 a
	ICMH 451	I	70.0 cd	5.6 ab	18.8 cde	5.1 b
		M	76.6 cde	5.1 bc	18.1 de	4.9 b
100	ICSV 745	I	86.6 bc	4.3 cd	22.2 abcd	13.7 a
		M	91.6 ab	4.5 de	22.5 abcd	16.4 a
	ICMH 451	I	63.3 e	4.6 cd	22.2 abcd	3.8 b
		M	73.3 cde	4.3 cd	22.0 abcd	5.9 b
115	ICSV 745	I	91.6 ab	3.9 d	25.8 a	14.0 a
		M	93.3 ab	4.3 cd	23.1 abc	14.7 a
	ICMH 451	I	66.6 de	4.4 cd	22.4 abcd	4.5 b
		M	78.3 cde	4.3 cd	23.4 abc	6.5 b
130	ICSV 745	I	93.3 ab	4.4 cd	23.4 abc	16.6 a
		M	93.3 ab	4.4 cd	23.3 abc	14.5 a
	ICMH 451	I	70.0 de	4.3 cd	22.6 abcd	4.7 b
		M	80.0 cde	4.4 cd	22.7 abcd	5.3 b
145	ICSV 745	I	91.6 ab	3.8 d	25.9 a	14.6 a
		M	95.0 a	4.2 cd	23.6 abc	14.5 a
	ICMH 451	I	80.0 cd	3.8 d	21.8 abcd	4.8 b
		M	80.0 cd	4.4 cd	25.5 ab	6.6 b

[1]Intercropping treatments: I = Intercropped with French Beans and M = Monocropped . [2]FGP = Final Germination Percentage. [3]MGT=Mean Germination Time. [4]CVG = Coefficient of Velocity of Germination. [5]DWS = Dry Weight of Shoot. 0g/l PEG: Dry, untreated seeds. Means in columns followed by similar letters are not significantly different according to Duncan's Multiple Range Test (5 %).

3 Results and Discussion

3.1 Intercropping with French Beans After PEG Priming

As indicated by Table 2 the sorghum variety ICSV 745 responded better than the pearl millet hybrid ICMH 451 to priming treatments, in FGP terms, regardless of PEG concentration. Intercropping did not significantly affect FGP in either genotype with all treatment combinations. PEG concentration neither had a significant effect on the FGP of intercropped nor monocropped ICSV 745 and ICMH 451 seeds. The MGT of unprimed ICSV 745 seeds did not differ from that of primed ones when the variety was intercropped with French beans. However, when planted alone primed seeds yielded lower MGTs (faster germination) than unprimed ones. Exactly the opposite occurred in ICMH 451 with a priming effect evident only in intercropped plants. Sorghum and millet seeds germinated better and faster, as reflected by higher CVG values, when primed and planted alone than when unprimed or primed and intercropped. As for seedling growth, neither priming treatment nor intercropping had any significant effects on the DWS (Table 2). The genotypes themselves did, however, differ in the DWS they attained, with ICSV 745 giving significantly higher DWS values than pearl millet ICMH 451 under all treatment combinations.

The germination results in Table 2, as mentioned, show no significant differences between untreated controls of both sorghum (ICSV 745) and pearl millet (ICMH 451) under both cropping systems. The viability of submitted seed samples from both lots, then, would be the same. This would mean that the differential response to PEG-priming by sorghum and pearl millet (Table 2) can be regarded as a true treatment effect and not a seed lot originated one. If the latter is true, different FGP's of controls would have been observed. The FGP (around 70-80 %) in controls tends to be somewhat low. The seeds were not exposed to severe stress of any kind, including water shortage, during the first 10 days as the 150 ml irrigation ration on the day of sowing represented 5.32% of the soil moisture content on an oven dry basis and the 100 ml thereafter was equivalent to 3.71%. In both cases this would have meant that there was enough moisture for germination at the 2 cm pot level where the seeds were sown and so an apparent reason for such low percentages is not available.

Priming with PEG did not significantly raise the FGP over controls, although, as PEG concentration increased so did the FGP. PEG is an inert material which has a number of important properties. Firstly, it readily dissolves in water. Secondly, it is a true osmoticum, i.e. unlike the molecules of inorganic salts, for example, the very large molecules of PEG cannot pass into plant cells. Thirdly, it is chemically inert and therefore permits prolonged pre-treatment without harming the seeds (HEYDECKER *et al.*, 1974). Additionally, the lower the molecular weight of the osmoticum, the more negative is the osmotic potential required to restrict water uptake by the seed (BROKLEHURST AND DEARMAN, 1984). Due to this capacity to create a negative osmotic potential in the solution without interfering with internal seed activities PEG has been classically used as a priming agent (HEYDECKER AND GIBBINS, 1978). One of its direct effects is slowing down imbibition (KANTAR, *et al.*, 1996) and reducing subsequent water uptake. The solubility of oxygen in PEG is, however, a problem and has been reported elsewhere (NIENOW AND BROKLEHURST, 1987). Other negative properties of PEG include increasing the viscosity of the solution (LAWLOR, 1970) thus reducing water uptake and oxygen supply even further. Our concentrations ranged from 100 to 145g/l (10 to 14.5 % w/v, respectively). This meant osmotic potentials ranging from -2.2 to -4.8 bar. Under priming standards where osmotic potentials as low as -2.5 MPa (-25 bar) have been reported (MUELLER, 1996), this is rather high (i.e. less negative Ψ_s). Primed seeds should have taken up a quantity of water during the treatment up to the osmotic potential of the priming solution (-2.2, -3.0, -4.0 or -4.8 bar) and this would have satisfied at least part of the minimum amount of water required for germination. It would also have meant, however, a lower seed suction force in comparison to the dry, untreated seeds which would have a much larger suction capacity to take up water from the surrounding medium (sand). And, since, as mentioned, water did not seem to be a limiting factor in the greenhouse trial, dry seeds may have compensated the amount of water taken up by primed seeds prior to sowing (during priming) by taking up more water after sowing (in the sand). Hence the insignificant differences in FGP which is a time independent germination parameter (water uptake is, on the other hand, very much time dependent), meaning that at the end of our 10 days germination scoring period any differences in water uptake between primed and untreated seeds would have diminished.

The insignificant differences between the four concentrations of PEG used may reflect an insignificant physiological role of the -2.6 bar difference between the highest and lowest osmotic potentials of the PEG treatments (-2.2 and -4.8 bar, respectively). In other words, the -2.2, -3.0, -4.0 and -4.8 bar were probably similar in their effects on the seed. The difference did show up, on the other hand, in time-dependent parameters like MGT and CVG. Primed, monocropped seeds germinated faster than unprimed ones. The CVG is a measure of both the FGP and the time needed to reach it. It lacks a unit but the higher the value, the more the seed lot germinated and the shorter time it took to do so. This means that owing to significantly higher CVG values, primed seeds would reach a higher FGP as unprimed ones in a shorter time. The fact that intercropping reduced the speed of germination in sorghum and not in pearl millet may have something to do with both seed size and competition for water.

If planted alone (monocropped), seeds (10 in all) would only need to overcome the matric resistance of the substrate to take up water. Intercropping, on the other hand, meant that sorghum or pearl millet seeds would have to compete with French bean seeds for water. We speculate that the high suction ability of the leguminous bean seeds meant that sorghum seeds would need a longer time to reach the critical hydration level necessary for germination. This was not observed in pearl millet seeds, probably due to their smaller size and, thus, the lower absolute water requirements they needed. A smaller seed size would also mean a larger surface area for water uptake (relative to size).

The rise in FGP in response to priming was, to a significant extent, affected by genotype. Sorghum responded better to priming than pearl millet even though it was a variety whereas millet was a hybrid. Hybrids usually respond to additional inputs in a much more pronounced manner than varieties or land races. This was not the case in the PEG treatments. This would tend to favour sorghum over pearl millet in applying such treatments even though the latter is better adapted to harsh environments where the potentials of seed priming should be better realized. Shoot growth as reflected by all three parameters was higher in sorghum than in pearl millet. This reflects the genetic difference between the species where sorghum is generally a larger and taller plant in comparison to the more compact millet.

Table 3: Interactive effects of seed treatment and genotype on germination characteristics of sorghum and pearl millet

Treatment	Genotype	FGP (%)	MGT (day)	CVG
Dry Control	M35-1	63.7 bc	5.5 ab	17.6 ef
	Barmer	70.0 abc	3.2 f	30.6 a
	ICSV 112	58.7 bc	6.1 a	16.7 f
PEG	M35-1	77.5 abc	3.9 cdef	25.2 abcd
	Barmer	85.0 a	3.4 ef	28.8 ab
	ICSV 112	72.5 abc	4.2 cdef	23.4 bcde
PEG + GA_3	M35-1	76.2 abc	3.8 cdef	25.3 abcd
	Barmer	75.0 ab	3.2 f	29.3 ab
	ICSV 112	63.7 abc	3.9 cdef	25.7 abcd
PEG + Urea	M35-1	68.7 abc	5.0 abc	20.4 def
	Barmer	68.7 abc	3.9 cdef	25.6 abcd
	ICSV 112	55.0 c	4.7 bcd	21.5 def
PEG + Sucrose	M35-1	78.7 ab	4.2 cdef	24.9 abcd
	Barmer	76.2 abc	3.5 def	28.4 abcc
	ICSV 112	76.2 abc	4.1 cdef	25.5 abcd
PEG + NaCl	M35-1	57.5 bc	5.0 abc	19.4 def
	Barmer	75.0 abc	4.0 cdef	25.4 abcd
	ICSV 112	65.0 bc	4.3 bcdef	22.9 bcdef
PEG + A. Acid	M35-1	70.0 abc	3.9 cdef	23.4 bcde
	Barmer	62.5 bc	4.6 bcde	22.0 cdef
	ICSV 112	60.0 bc	4.7 bcd	20.8 def

Means in columns followed by similar letters are not significantly different according to Duncan's Multiple Range Test (5 %). A. Acid: Ascorbic acid, FGP: Final Germination Percentage, MGT: Mean Germination Time and CVG: Coefficient of Velocity of Germination.

3.2 Enhancement of PEG with Growth Regulator and Salt Additives

The analysis of interactions showed that the FGP was not significantly affected by priming treatment or genotype (Table 3). Pooled over the three genotypes, however, PEG (T_2) and PEG + Sucrose (T_5) gave significantly higher FGP values than the other four treatments and the dry control (Table 3). In both sorghum varieties M35-1 and ICSV 112 untreated seeds needed significantly longer periods to germinate than those primed in any one of the six solutions. No differences were observed between the priming solutions themselves in this regard. The germination speed of Barmer, the pearl millet variety, was not affected by treatment. The longest overall MGT was found in dry, untreated seeds, whereas PEG + GA_3 produced the lowest MGT and, thus, the fastest germinating seeds.

Both sorghum varieties responded to priming by increasing the CVG over control seeds (Table 3). This held true for treatments other than PEG + NaCl where such a trend was not observed. PEG + GA_3 and PEG + Sucrose appeared to induce the highest increase in CVG values. All treatments considered, pearl millet had a higher FGP than ICSV 112 and a similar one to M35-1. It also gave lower MGT and higher CVG values than both.

At 14 days of age, M35-1 seedlings from T_3-treated seeds (PEG + GA_3) gave the highest shoot length values (SL_{14}) in comparison to other treatments and varieties. Generally, M35-1 produced taller plants than both ICSV 112 and Barmer (Table 4) and this manifested itself in higher dry weights (DWS_{14}), again, with PEG + GA_3 giving the highest values. PEG + GA_3 and M35-1 maintained this higher level of shoot length up to 21 days (SL_{21}) in comparison to other treatment combinations. Root length, measured on the 21st day after sowing (RL_{21}), on the other hand, was similar for all treatments and genotypes. On a dry weight basis, M35-1 shoots were heavier than those of ICSV 112 and Barmer which, like treatments, did not differ amongst each other. The same applied to DWR_{21}, except that the PEG + Ascorbic acid treatment yielded the highest dry root values (Table 4). The relationship between shoot and root was affected by priming treatment. The SRR was highest in PEG + GA_3 and lowest in PEG + Ascorbic acid.

The results of the phytotron trial provide further evidence of advancement of germination speed by priming even though a clear-cut increase in final germination percentage was not observed confirming earlier reports (HEYDECKER *et al.*, 1974; YONG QUING *et al.*, 1996). In contrast to the intercropping trial conducted under unlimited conditions in the greenhouse, the phytotron tests included partial moisture and temperature stress. All the same, PEG treatments did improve the quality of germination under these conditions. This would tend to imply that the treatments used are relatively robust in the sense that they affected germination in both unstressed and stressed cases.

Generally, the data suggests that the osmotic effect of a priming agent seems to be of major importance in manipulating the seed water status. However, an addition of the growth regulator gibberellic acid (GA_3) further enhanced this effect. Kuhad *et al.* (1987), working with pearl millet, also observed an enhancement of germination and radicle growth in 10 ppm GA_3-treated seeds. Gibberellic acid controls a wide range of physiological functions in plants including those associated with the aleurone layer (BUSH, 1996) which directly affects germination. In a recent comparison between PEG priming and GA_3 treatment, YONG QING *et al.* (1996) observed that PEG priming did not promote DNA replication whereas GA_3 did, thus enhancing the germination process. On the other hand, reports of PEG (20% w/v) alone enhancing the germination of sorghum are also found in the literature (HUR, 1990 and 1991). The use of inorganic salts as osmotica has been documented (PILL *et al.*, 1991), but a major setback has been the penetration of ions into the seed. This disturbs the osmotic balance of the cells and increases ionic concentration disrupting enzymes and membranes leading to reduced germination (BROCKLEHURST AND DEARMAN, 1984). This may have been the case in the PEG + NaCl treatment which did not yield satisfactory results. Cation uptake has been observed to increase in pearl millet seeds which are salt-soaked (PUNTAMKAR *et al.*, 1987).

Table 4: Interactive effects of seed treatment and genotype on growth characteristics of sorghum and pearl millet

Treatment	Genotype	SL_{14} (cm)	DWS_{14} (mg)	SL_{21} (cm)	RL_{21} (cm)	DWS_{21} (mg)	DWR_{21} (mg)	SRR
Dry Control	M35-1	10.7 b	23.0 a	11.9 abcd	16.1 a	26.9 abcd	29.5 bcde	0.89 abcd
	Barmer	6.5 defg	7.5 de	10.5 cde	17.1 a	15.8 cd	15.4 de	1.1 ab
	ICSV 112	5.0 fg	8.0 de	11.1 bcde	17.5 a	18.8 bcd	22.7 bcde	0.7 abcd
PEG	M35-1	10.5 b	22.7 a	13.3 abc	19.9 a	35.4 ab	31.4 bcde	1.0 ab
	Barmer	6.7 defg	6.3 e	7.8 de	17.4 a	9.4 d	17.8 cde	0.7 abcd
	ICSV 112	6.7 defg	11.8 cd	10.4 cde	15.2 a	19.9 bcd	21.3 cde	0.9 abcd
PEG + GA_3	M35-1	13.0 a	25.0 a	15.6 a	20.5 a	35.1 ab	46.6 ab	1.1 ab
	Barmer	7.4 def	7.0 e	11.6 bcd	21.7 a	22.0 abcd	16.3 de	1.2 a
	ICSV 112	7.0 defg	10.3 cde	10.1 cde	14.2 a	17.3 cd	25.2 bcde	0.8 abcd
PEG + Urea	M35-1	6.3 defg	13.9 bc	14.8 ab	16.3 a	37.7 a	46.6 ab	0.8 abcd
	Barmer	6.5 defg	7.7 de	10.7 cde	20.2 a	14.1 d	16.3 de	0.8 abcd
	ICSV 112	7.8 cde	9.5 de	11.1 cde	17.7 a	21.5 abcd	25.2 bcde	0.9 abc
PEG + Sucrose	M35-1	9.9 bc	21.1 a	13.2 abc	20.2 a	32.0 abc	42.2 abc	0.7 abcd
	Barmer	7.1 defg	8.9 de	8.7 de	21.0 a	11.1 d	10.9 e	0.9 abc
	ICSV 112	5.7 efg	11.0 cde	9.1 de	17.9 a	14.7 cd	21.6 cde	0.7 abcd
PEG + NaCl	M35-1	8.0 cde	16.3 b	13.3 abc	17.9 a	32.3 abc	33.5 bcde	0.9 abc
	Barmer	6.2 defg	7.7 de	8.7 de	18.5 a	12.2 d	15.6 de	0.8 abcd
	ICSV 112	5.0 fg	8.9 de	10.1 cde	20.1 a	16.8 cd	25.2 bcde	0.7 bcd
PEG + A. Acid	M35-1	8.7 bcd	22.4 a	11.8 abcd	18.3 a	37.4 a	58.6 a	0.8 abcd
	Barmer	5.4 ef	7.2 de	7.0 e	19.4 a	9.5 d	21.9 bcde	0.4 d
	ICSV 112	4.5 g	7.1 de	9.3 cde	16.6 a	19.0 bcd	37.8 abcd	0.5 cd

Means in columns followed by similar letters are not significantly different according to Duncan's Multiple Ranget Test (5 %). A. Acid: Ascorbic acid, SL_{14}: Shoot Length at 14 days of age, DWS_{14}: Dry Weight of Shoot at 14 days of age, SL_{21}: Shoot Length at 21 days of age, RL_{21}: Root Length at 21 days of age, DWS_{21}: Dry Weight of Shoot at 21 days of age, DWR_{21}: Dry Weight of Root at 21 days of age, and SRR: Shoot to Root Ratio. M35-1 and ICSV 112 are sorghum, and Barmer is a pearl millet variety(ies), respectively.

Growth, which can be defined as an increase in dry weight, length or area, was affected by seed treatment, at least as much as the shoot was concerned. This agrees with other reports like that of KANG AND CHO (1996) where primed water melon seeds produced plants with greater fresh and dry weights. It is hypothesized that the advancement in shoot growth was attained through earlier radicle emergence from primed seeds (Table 3). However, this may not account for all the difference in growth because the decrease in MGT caused by priming did not exceed 2 days at the most and so this gain in growth could be possibly ascribed to another effect of priming. Priming did not affect root growth on the other hand, and although this agrees with the data of BECKMAN *et al.*

(1993) it is not clear why. Generally, from the SRR values it would seem that GA_3 caused greater shoot growth at the expense of roots, whereas ascorbic acid did exactly the opposite through its induction of root growth. A certain relationship between shoots and roots, then, may have governed this response.

On a genotypic basis, pearl millet responded less to priming than sorghum, but pooled over treatments it had a higher FGP and CVG, and lower MGT values. However, in growth terms it grew either less or similarly to ICSV 112, the slower growing of the two sorghum varieties, thus confirming results of the first experiment.

In conclusion, it would seem that seed priming of sorghum or pearl millet may yield satisfactory results as far as the enhancement of germination speed is concerned. This advancement appears to be better illustrated when a monocropping system is used in comparison to intercropping.

4 Summary

In order to study the performance of primed sorghum and millet seeds under intercropped or monocropped planting systems, and to investigate the possibilities of enhancing the osmotic effects of polyethylene glycol (PEG) with salt or growth regulator additives, two experiments were conducted in the greenhouse and phytotron. Intercropping primed seeds with *Phaseolus vulgaris* L. did not affect germination percentage but reduced germination speed as compared to primed, monocropped seeds. This was ascribed to effects of competition for water and to seed size. Neither priming treatment nor cropping system affected seedling growth in the genotypes studied. Priming treatments with PEG and other additives increased the speed of germination. The PEG and PEG + Sucrose treatments yielded the highest germination percentages, and PEG + GA_3 the highest germination speed. Mixing PEG with NaCl or ascorbic acid yielded lower germination percentages and longer germination periods.

Auflauf- und Wachstumseigenschaften von Sorghum und Perlhirse im Mischanbau mit Ackerbohnen nach PEG-unterstützten Saatgut-Vorbehandlungen (Priming) unter Gewächshaus- und Klimakammer-Bedingungen

Zusammenfassung

Um die Leistung von vorbehandeltem (primed) Sorghum- und Perlhirse- Saatgut unter Rein-und Mischkultur-Anbausystemen zu prüfen, wurden zwei Versuche im Gewächshaus und in der Klimakammer durchgeführt. Die Förderung der PEG-Effekte in der Saatgut-Vorbehandlung durch Kochsalz und Phytohormone wurde ebenfalls untersucht. Der gemischte Anbau von behandeltem Sorghum und Perlhirse-Saatgut mit *Phaseolus vulgaris* L. hatte keine Wirkung auf die endgültige Keimrate, reduzierte aber die Keimrate im Vergleich zu behandeltem, einzel-angebautem Saatgut. Es wird vermutet, daß die Konkurrenz um Wasser und die Samengröße dabei eine Rolle spielten. Saatgut-Vorbehandlungen mit PEG und zusätzlichen Substanzen fuhrten zu einer Zu-

nahme der Keimrate. Die PEG- und PEG + Sacharose-Behandlungen zeigten die höchste Keimrate, und PEG + GA_3 zeigte die höchste Keimgeschwindigkeit. Das Mischen von PEG mit NaCl oder Ascorbinsäure ergab niedrigere Keimraten und längere Keimdauer.

5 References

1. AL-MUDARIS, M. AND JUTZI, S., 1997a, Germination of *Sorghum bicolor* L (Moench) under heat and drought stress as affected by NaCl seed priming. International Conference on Sustainable Agriculture for Food, Energy and Industry, Braunschweig, Germany, Book of abstracts, p. 304.
2. AL-MUDARIS, M. AND JUTZI, S., 1997b, The role of growth regulator seed soaks in the response of a local Indian pearl millet landrace to supra-optimal temperatures during the first three days after sowing. Technisher Fortschritt im Spannungsfeld von Ernaehrungssicherung und Ressourcenschutz, Tropentag Stuttgart-Hohenheim, Book of Abstracts, p.73.
3. BUSH, D., 1996, Effects of gibberellic acid and environmental factors on cytosolic calcium in wheat aleurone cells. Planta 199, 89-99.
4. BROCKLEHURST, P. AND DEARMAN, J. , 1984, A comparison of different chemicals for osmotic treatment of vegetable seed. Annals of Applied Biology 105, 391-398.
5. BECKMAN, J., MOSER, L., KUBIK, K. AND WALLER, S., 1993, Big Bluestem and Swithgrass establishment as influenced by seed priming. Agronomy Journal 85, 199-202.
6. HEYDECKER, W., HIGGINS, J. AND GULLIVER, R., 1974, Instant germination-a method of brinkmanship. Commercial Grower 4, 17-21.
7. HUR, S., 1990, Effect of osmoconditioning on germination of Italian ryegrass and sorghum. Journal of the Korean Society of Grassland Science 10, 121-128.
8. HUR, S., 1991, Effect of osmoconditioning on the productivity of Italian ryegrass and sorghum under suboptimal conditions. Korean Journal of Animal Sciences 33, 101-105.
9. JAHNCKE, H, 1982, Livestock Production Systems and Livestock Development in Tropical Africa, Varik Verlag.
10. JONES, K. AND SANDERS, D., 1987, The influence of soaking pepper seed in water or potassium salt solutions on germination at three temperatures. Journal of Seed Technology 11, 97-102
11. KHISTARIA, M. AND SADARIA, S.,1995, Studies on pearl millet mixed cropping with pulses under dry farming condition. Journal of Maharashtra Agricultural Universities 20, 97-98.
12. KUHAD, M., SHEORAN, I. AND KUMARI, S., 1987, Alleviation and separation of osmotic and ionic effect during germination and early seedling growth in pearl millet by presoaking the seeds with growth regulators. Indian Journal of Plant Physiology 30, 139-143.
13. KANG, J. AND CHO, J., 1996, Effect of priming on the germinability of watermelon (Citrullus vulgaris Schrad) seeds and seedling growth. Journal of the Korean Society for Horticultural Science 37, 12-18.
14. KANTAR, F., PILBEAM, C. AND HEBBLETHWAITE, P., 1996, Effect of tannin content of faba bean (Vicia faba) seed on seed vigour, germination and field emergence. Annals of Applied Biology 128, 85-93.
15. LAWLOR, D., 1970, Absorption of polyethylene glycols by plants and their effects on plant growth. New Phytologist 69, 501-513.
16. NIENOW, A. AND BROCKLEHURST, P., 1987, Seed preparation for rapid germination-engineering studies. pp 52-55 in Moody, G. and Baker, P. (Eds.) Bioreactors and Biotransformations. London, Elsevier.
17. ORCHARD, T., 1997, Estimating the parameters of plant seedling emergence. Seed Science and Technology 5, 61-69.
18. OFORI, F. AND STERN, W., 1987, Cereal-Legume intercropping systems. Advances in Agronomy 41, 41-90.
19. PILL, W., FRETT, J. AND MORNEAU, D., 1991, Germination and seedling emergence of primed tomato and asparagus seeds under adverse conditions. HortScience 26, 1160-1162.

20. PUNTAMKAR, S., KANT, K. AND MATHUR, S., 1987, Effect of soaking of seeds on the yield and uptake of cations by hybrid bajra on salt affected soils. Transactions of the Indian Society of Desert Technology 12, 99-104.

21. WANI, A., MAHAJAN, V. AND UMRANI, N., 1994, Alley cropping of forages in subabul for quality herbage yields. Journal of Maharashtra Agricultural Universities 19, 34-37.

22. YONGQING, L., BINO, R., VAN DER BURG, W., GROOT, S. AND HILHORST, H., 1996, Effects of osmotic priming on dormancy and storability of tomato (Lycopersicon esculentum Mill.) seeds. Seed Science Research 6, 49-55.