

EFFECTS OF SEED PRIMING ON CHLOROPHYLL CONTENT AND YIELD COMPONENTS OF PINTO BEANS

FATEMEH MOHAJERI¹, MAHMOUD RAMROUDI², MANSOUR TAGHVAEI³, MOHAMMAD
GALAVI²

1- PhD Student in Department of Agronomy, Faculty of Agriculture, University of Zabol, Iran

2-Associate Professor in Department of Agronomy, Faculty of Agriculture, University of Zabol, Iran

3- Associate Professor in Department of Agronomy, Faculty of Agriculture, Shiraz University, Iran

*Correspondence: Mansour Taghvaei: Department of crop production and plant breeding, Faculty
of Agriculture, Shiraz University, Iran, Tel: +98-917-720-3455; E-mail: taghvaei@shirazu.ac.ir

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ABSTRACT

Seed priming on chlorophyll content, yield and yield components of pinto beans in a completely randomized design with split plot platform. The main plots was three levels of pinto bean varieties including E9, E10, and Khomain; and the subplots were seven pretreatments including - 5 bar of polyethylene glycol at 6 hours, 500 mg per liter salicylic acid at 12 hours, -20 mM potassium chloride at 6 hours, -15 mM calcium chloride at 3 hours, -15mM sodium chloride at 6 hours, water at 12 hours, and control (without pretreatment). The results showed that pretreatments had a significant effect on yield and yield components ($P < 0.05$). The highest 100 seed weight, number of seed in pod, number of pods, pods length, total chlorophyll, a, b, biological yield, and grain yield were observed in water at 12 hours and calcium chloride at 3 hours. Pretreatments proving that these two methods of pretreatments were the most effective ways on yield and yield components. The results of principle component analysis have also showed that indirect selection via number of seed in plant and seed weights, which have higher heritability relative to seed yield, could be selected for genetic improvement of plant yield.

Keywords: Seed priming; pinto bean; chlorophyll; principle component analysis, yield

1. INTRODUCTION

Beans as the second source of human food after cereals (Salehi, 2005) could be used as the cheapest but the most convenient alternative feeds in animal nutrition containing almost 22% crude protein, 62% starch, and 2% lipid material. The combination of cereals and legumes may warrant high-quality protein source in human nutrition that could overcome malnutrition issues resulting from imbalance of essential amino acids (Majnoon-Husseini, 2005). It has been shown that pretreatment of seed may increase germination and subsequently improve the initial strength of seeds. Moreover, the high performance could be achieved through increasing the emergence percentage and seedling rate (Parera and Cantliffe, 1994). When seeds were primed after planting in bed, they were germinated sooner, quicker, and better with uniform growth pattern at the time. In fact, the primed seeds extend their root systems with better water and nutrient absorption resulting in larger photosynthetic production of green areas compared to untreated seeds (Duman, 2006). Priming via improvement of germination before cell division in seed operated speed and percentage of germination (Lanteri et al., 1996). Scientists

using priming techniques germination percentage, rate, and emergence of different plants have increased the stability of the seedlings, competition with weeds, and crop yield (Abbasdokht and Edalatpisheh, 2012) as well as increasing germination by reducing damage to proteins, RNA-DNA (Farooq et al., 2009). Jamal et al. (2011) investigated the impact of priming on growth and chemical properties of green leaf of wheat and reported that chlorophyll b had been significantly increased by seed priming. Sarmadi et al (2014) have declared the significant effect of seed priming with potassium nitrate on pinto beans. Golezani Ghasemi et al (2010) have reported the effectiveness of hydro priming on seedling vigor and seed yield of pinto. The effect of seed priming on seed yield and yield components of pinto beans have reported by Hajikhani et al (2011). The aim of this study was to investigate the effects of pretreatments on yield and yield component of pinto beans. In general, seed priming can help crop plants to cope with stress factors, such as drought and pest damage increasing crop yield (Harris et al., 1999, 2000). The results showed that all studied traits affected by priming treatment significantly. Seed

priming has been used to improve germination, reduce seedling emergence time, and improve stand establishment and yield (Khan, 1992). The beneficial effects of priming have been demonstrated for many field crops such as barley (Abdulrahmani et al., 2007), maize (Parera and Cantliffe, 1994), lentil (Ghassemi-Golezani et al., 2008a), chickpea (Ghassemi-Golezani et al., 2008b), sugar beet (Sadeghian and Yavari, 2004) and sunflower (Singh, 1995). These effects of priming are associated with the repairing and building up of nucleic acids, increased synthesis of proteins as well as the repairing of membranes (McDonald, 2000). Priming also enhances the activity of anti-oxidative enzymes in treated seeds (McDonald, 1999; Wang et al., 2003; Hsu et al., 2003). Moreover, priming increases the activity of glyoxysome enzymes in primed bitter melon seeds (Lin and Sung, 2001). Earlier works showed that the success of seed priming is influenced by the complex interaction of factors including plant species, water potentiality of priming agent, duration of priming, temperature, seed vigor, and storage conditions of the primed seeds (Parera and Cantliffe, 1994). Among priming agents, water increased seed yield, 100 seed weight, number of seeds per plant, number of

pods, and total chlorophyll more than other substances. It has been reported that hydro-priming is a very simple, economic, and environmental friendly type of seed priming (Thornton and Powell, 1992; Ghassemi-Golezani et al., 2008a). Also Ghassemi-Golezani et al (2010) have reported that hydro-priming can be successfully applied to enhanced seed and seedling vigor, stand establishment, and grain yield of pinto bean cultivars in the field. They also concluded that this improvement was reflected in low electrical conductivity (EC) of seed leachates and mean germination time and high germination percentage and seedling dry weight. It was shown that seed priming causes metabolic changes in germinating seed, such as cell cycle related events (De Castro et al., 2000), endosperm weakening by hydrolase activities (Groot et al., 1988; Bradford et al., 2000) and mobilization of storage proteins (Job et al., 2000). However, positive effects of seed priming on seed invigoration depends on priming duration (Ashraf and Foolad, 2005; Ghassemi-Golezani et al., 2008b). When seeds imbibe, the water content reaches a plateau and changes little until radicle emergence (Bradford, 1986). Better emergence of seedlings from hydro-primed seeds for 12

hours suggests that proper priming duration can ensure optimum plant establishment of pinto bean cultivars in the field. Under field conditions, the rate of seedling emergence and establishment is critical (Kaufmann and Eckard, 1977). Rapid and uniform field emergences of seedlings are two essential pre-requisites to increase yield, quality and ultimately profit in annual crops (Finch-Savage, 1993). Rapid emergence of seedlings could lead to the production of vigorous plants (Ghassemi-Golezani et al., 2008b). Selection for seed yield and production of the cultivars with high yield potential is the main objective of breeding programs. Many researchers (Quarrie et al., 1999; Richards, 1996) believed that genetic improvement of seed yield must be done via genetic improvement of physiological traits. In determining the potential of genetically different lines and cultivars, the experts have to consider many different characters that influence the yield. Indirect selection in early generations through traits correlated with seed yield is one of the most important strategies in plant breeding. Principal component analyses help researchers to distinguish significant relationship between traits. This multivariate analysis method aims to explain the correlation between a large set

of variables in terms of a small number of underlying independent factors. In conclusion, indirect selection via number of seeds per plant and seed weight, which have higher heritability relative to seed yield, is emphasized in this study for genetic improvement of plant yield. Beheshtizadeh et al. (2013) and Evgenidis et al. (2011) have also used principal component analyses as a useful tool in the assessment of crop cultivars.

2. MATERIAL AND METHODS

An experiment was carried out to evaluate the effect of seed priming on chlorophyll content, yield and yield components of pinto beans in a completely randomized design with split plot platform. The main plots was three levels of pinto bean varieties including E9, E10, and Khomain; and the subplots were seven pretreatments including -5 bar of polyethylene glycol at 6 hours, 500 mg per liter salicylic acid at 12 hours, -20 mM potassium chloride at 6 hours, -15 mM calcium chloride at 3 hours, -15mM sodium chloride at 6 hours, water at 12 hours, and control (without pretreatment). The seeds of pinto bean cultivars were prepared from the Fars Research Center for Agriculture and Natural Resources (FRCANR, Eghlid, Iran) and maintained in plastic packages with

minimum permeability at 5°C until the beginning the study. The experiment was conducted in several stages. First level (Mohajeri *et al.*, 2015) and is suitable for pre-treatment period, respectively. Then seeds obtained with the best levels and duration was pretreated in the laboratory. 360 seeds in each treatment were used. Upon completion of the pre-treatment to the seeds pre-treated by washing with distilled water and all the seeds for 48 hours to reach the initial weight was dried at room temperature (ISTA, 2008). On 22 May 1393 the seeds were planted in the field. Before planting, the seeds were primed in the laboratory and then were planted in the spring. The fields were ploughed and harrowed, which were divided into three replications each with 63 plots per replication. Each plot consisted of six rows of planting with 2m length. Inter and intra-row spacing was 30cm x 10cm. The seeds were sown in the suitable depth (3-4cm). Extraction and determination of chlorophyll was performed according to the method of Arnon (1967) and the following formula:

$$\text{Total chlorophyll (mg/ml)} = A (652) / 34.5 \times V/W$$

$$\text{Chlorophyll 'a' (mg/ml)} = [12.7 (A663) - 2.69(A645)] \times V/W \times 1000$$

$$\text{Chlorophyll 'b' (mg/ml)} = [22.9(A645) - 4.68(A663)] \times V/W \times 1000$$

A = absorption of light at wavelengths of 663, 645 and 652 nm

V = the volume of the filtrate (upper solution of centrifuges)

W = weight of sample in grams

The amount of 0.2 g of fresh leaf material was ground with 25 ml of 80% acetone and centrifuged at 4000 rpm for 10 minutes at 4°C. The extract was transferred to a graduated tube and made up to 10 ml with 80% acetone. Thereafter, 3 ml aliquots of the extract were transferred into a cuvette and absorbance was read at 645, 663 and 625 nm with a spectrophotometer (Model S2 100 Diode Array England) against 80% acetone as blank. To measure yield components, 10 plants were randomly selected from each experimental unit and yield components including pod length in the main and secondary branches per plant, number of seeds per pod the main and secondary branches, and 100 seeds weight were measured. In order to quantify the yield after harvesting, 1 m² of each plant was taken the test unit plots and after measuring biological traits, the grain yield and harvest index were calculated. The soil texture was clay and the analysis of soil is shown in Table 1. These data were analyzed using SAS software version 9.1 and the differences between the means compared using Duncan's at the 5% level.

Table 1: Soil properties of experimental field

Clay	Textured Soil			N	P	K	pH	EC
	Sandy%	Clay%	Silt%	(ppm)	(ppm)	(ppm)		
	18.84	42.44	38.72	119	12	330	6.92	0.631

3. RESULTS

3.1. Seed weight

Seed weight was significantly affected by pretreatments (Table 2). The means comparison showed that the highest and lowest seed weight of optioned with pretreatment with H₂O 12 hours and control respectively (Table 4). There was no difference between H₂O at 12 hours and CaCl₂ at 3 hours. There was no significant difference between treated PEG at 6 hours, NaCl at 6 hours KCl a 6 hours and SA at 12 hours (Table 4). Pretreatment increased seed weight. Similar result was reported by Mansouri and Aboutalebian, 2013 in pea. Golezani Ghasemi et al., 2014 reported this may be due to increased endosperm cell division and cytokinin activity and thus improve the grain filling rate.

3.2. The number of seeds per plant

Pretreatment had a significant effect on the number of seeds per plant (Table 2). The mean comparison showed that treated H₂O at 12 hours and control had the highest and lowest number of seeds per plant respectively (Table 4). Treated H₂O at 12 hours, CaCl₂ at 3 hours and PEG at 6 hours and NaCl at 6

hours did not show any significant difference. Between SA at 12 hours, KCl at 6 hours and control not difference was observed (Table 4). The Number of seeds per plant was significantly affected by bean cultivars Bean (Table 2). The study compared the E9 and the khomein cultivars the highest and lowest number of seeds per plant, respectively (Table 4). Golezani Ghasemi et al., 2010 reported similar results in pea plants. Kaur et al., 2005 reported that sink activity via increased enzyme activities, metabolism of sucrose such as Syntetaz sucrose, envertaz and sucrose phosphate Synthetize in primed pea seeds were more than non-primed seeds and there was the increase in the number of seeds and yield.

3.3. Number of seeds per pod

The number of seeds per pod is one of the most important components to achieve optimum economic yield the number of seed per pods was affected by pretreatment (table 2). The number of seeds per pod was significantly affected by the treatments (Table 2). The highest and lowest number of seeds per pod were seen in pre-treatment CaCl₂ at 3 hours and control respectively

(Table 4). No significant difference was observed between numbers of seeds per pod the pre-treatment water at 12 hours and CaCl_2 at 3 hours and between NaCl at 6 hours and PEG at hours. Similar result was reported by Latif zadeh et al., 2013 and Ghasemi Golezani et al., 2010 in Bean.

3.4. Number of seeds per pod subsidiary

The number of seeds per pod subsidiary was significantly affected by Pretreatment (Table 2). Comparison pretreatment with CaCl_2 at 3 hours and KCL at 6 hours showed the highest and lowest number of seeds per pod subsidiary (Table 4). No significant differences difference observed between number of seeds per pod subsidiary in pretreatment of CaCl_2 at 3 hours, H_2O at 12 hours and NaCl at 6 hours and between KCL, PEG at 6 hours, SA at 12 hours and control (Table 4). Rastin et al., 2013 reported priming increased grains and yield in red bean varieties. In this regard, Ghasemi Golezani et al., 2010 reported that yield improvement of primed bean indirectly with the increase in seedling and number of seeds per square meter

3.5. The number of pods

The number of pods was significantly affected by pretreatments (Table 2). The mean comparison showed that the number of

pods were maximum at pre-treatment H_2O at 12 hours and minimum at the control (Table 4). Pre-treatment of H_2O at 12 hours, CaCl_2 at 3 hours, PEG and NaCl at 6 hours did not show any significant differences. Also between pretreatment KCL at 6 hours and SA at 12 hours there was no significant difference (Table 4). The number of pods was significantly was affected by cultivars (Table 2). E9 cultivar and khomein had the Maximum and minimum number of pods respectively (Table 4). Similar result was reported by Kaur et al., (2005) in the pea plant. Rastin et al., 2013 in red beans and Mohagheghi and Aboutalebian, 2013 in rapeseed showed that priming increased the number of pods per plant.

3.6. Total chlorophyll, a and b

Pretreatment had a significant effect on the total of chlorophyll (Table 3). The comparison showed that pre-treatment H_2O at 12 hours and SA at 12 hours showed the highest and lowest total chlorophyll respectively (Table 5). Although no significant differences was observed between the pretreatment of H_2O at 12 hours and CaCl_2 at 3 hours (Table 5). Chlorophyll A was significantly affected by the pretreatments (Table 3). The comparison showed pretreatment CaCl_2 at 3 hours and

SA at 12 hours to highest and lowest chlorophyll A respectively (Table 5). Significant differences were observed between pretreatment of H₂O at 12 hours and CaCl₂ at 3 hours. Chlorophyll b. Pretreatment had a significant effect on chlorophyll b (Table 3). The mean comparison showed the pre-treatment H₂O at 12 hours SA at 12 hours caused the highest and lowest chlorophyll b Respectively (Table 5). Significant differences were not observed between pretreatment H₂O at 12 hours and CaCl₂ at 3 hours. Similar result was reported by (momeni et al., 2013 and Jamal et al., 2011).

3.7. Biological yield

Biological yield was significantly affected by the pretreatments (Table 3). The highest and lowest minimum biological yield (square meter) were found in pre-treatment with PEG at 6 hours and control respectively (Table 5). Pinto bean cultivars were significantly affected by pre-treatment (Table 3). The highest and lowest biological yield shown in the cultivars, were E9 and E10 respectively (Table 5). Mansouri and Aboutalebian, (2013) and (Latif zadeh et al., 2013) reported the positive effect of Priming biological yield.

3.8. Yield

Yield in a square meter was significantly affected by the pretreatments (Table 3). The mean comparison observed that pre-treatment with H₂O at 12 hours and control were the highest and lowest grain yield in a square meter respectively (Table 5). (Fateh et al., 2010) on peas, (Rastin et al., 2013) on Beans, (Sarmadi et al., 2014) on pinto beans, (Kouchebagh et al., 2014) on Sunflower and (mohagheghi and Aboutalebian, 2014) on rapeseed reported similar results. (Kaur et al., 2005) reported that pretreatment increased the grain yield via of increasing of enzymes of sucrose metabolism.

3.9. Component analysis and the correlations between traits

The results of principal component analysis based on 10 characters showed that the first 3 components were covered 68.79% percentage of the total variation (Table 6). The first PC explained 41.220% of total variance, which was positively correlated with NSPP, NSPPd, NSPPds, and NP indicating that the PC1 is mainly associated with yield variables. However, some negative correlations were observed between yield variables and chlorophyll content (Table 6). The second PC explained 16.657% of total variance, which was positively associated

with chlorophyll contents of plants indicating that the PC2 is corresponded to the leaf quality (Table 6). The PC3 accounted for 10.915% of total variance and the most important variables for PC3 were SY, BY, and 100SW (Table 6).

The correlation analysis showed a significant and positive correlation of seed yield with number of seeds per plant, number of seeds per pod, number of pods, pods length in main stem and branches, total chlorophyll, chlorophyll a, seed length and seed width (Table 8).

Variation associated with variables in each component is independent from that in another component, therefore we can plot two components orthogonally showing loading plots (Figure 1 and 2). The most important variables associated with PC1 were yield traits including NSPP, NSPPD, and NSPPDS. Since PC1 mostly explains the

variation of yield traits, we call it as yield component. As shown in Figure 1, there was no correlation between yield traits and chlorophyll indices (quantity or quality) and genetic selection for seed yield may not affect the chlorophyll content and quality.

Loading plot of PC3 vs PC1 shows the negative correlation between biological yield (BIOY) and two yield variables including NSPPD and NSPPDS (Figure 2). This may explain that why unlimited growth in Pinto bean could limit the seed production through redirection of essential nutrient to flowering and vegetation rather than pods and seed production. Therefore, implementation of breeding program for maximizing BIOY may significantly reduce the seed number per pods.

Table 2: Analysis of variance of yield components of pinto beans

S.O.V	d.f	100 Seed weight (gr)	Numbers of seed per plant	Numbers of seed per pod subsidiary	Numbers of seed per pod	Numbers of pod per plant
Pretreatment	6	0.49**	646.31**	0.92**	1.33**	23.04*
Sub error	14	0.28	167.51	0.23	0.19	5.08
Cultivars	2	0.009 ^{ns}	523.44*	0.05 ^{ns}	0.16 ^{ns}	26.77*
p *c	12	0.074 ^{ns}	156.07 ^{ns}	0.24*	0.25 ^{ns}	5.53 ^{ns}
Error	28	0.083	148.46	0.11	0.18	6.95
CV		8.94	29.23	7.74	9.51	27.59

* and **, significant at 0.01 and 0.05 probability level, respectively, and ns: not significant

Table 3: Means comparison of pretreatments on yield components of pinto beans

Treatment	100 Seed weight (gr)	number of seeds per plant	Number of seeds per pod subsidiary	Number of seeds per pod	Number of pods per plant
PEG 6 hours	3.11ab	44.22ab	4.18bc	4.37c	10.44ab
Nacl 6 hours	3.27ab	47.11ab	4.22bc	4.46ab	11.11a
Cacl ₂ 3 hours	3.49a	47.66ab	4.74a	5.00a	9.89ab

AS12 hours	3.08ab	34.33bc	4.00c	4.08c	8.33bc
Kcl 6 hours	3.07ab	35.11bc	3.87c	4.02c	8.55bc
H ₂ O 12 hours	3.57a	53.11a	4.61ab	4.86ab	11.44a
Control	2.96b	30.22c	4.06c	4.13c	7.11c
E9	3.2ab	47.23a	4.29a	4.49a	10.81a
E10	3.25ab	40.23ab	4.23a	4.44a	9.23ab
Khomain	3.21ab	37.57b	4.20a	4.32a	8.61b

Means with similar letters in each column are not significantly different according to Duncan's multiple range tests at the $P < 0.05$ level

Table 4: Analysis of variance of chlorophyll and seed and biological yield of pinto beans

S.O.V	d.f	Chlorophyll a	Chlorophyll b	Total chlorophyll	Seed yield	Biological yield
pretreatment	6	0.11**	0.107**	0.42**	117.83**	208.57**
Sub error	14	0.012	0.024	0.034	28.78	95.94
Cultivars	2	0.03*	0.006 ^{ns}	0.063*	45.63 ^{ns}	36.95 ^{ns}
p *c	12	0.014 ^{ns}	0.007 ^{ns}	0.035 ^{ns}	21.92 ^{ns}	23.77 ^{ns}
error	28	0.007	0.013	0.022	697.05	1356.16
CV		7.47	12.28	7.02	24.61	16.74

* and **, significant at 0.01 and 0.05 probability level, respectively, and ns: not significant Table

Table 5: Mean comparison of pretreatments on chlorophyll content, seed and biological yield of pinto beans

Treatment	Chlorophyll a	Chlorophyll b	Total chlorophyll	Seed yield (ton.ha ⁻¹)	Biological yield (ton.ha ⁻¹)
PEG 6 hours	1.14b	0.89b	2.04b	0.65bc	1.48a
Nacl 6 hours	1.10b	0.84b	1.94b	0.64bc	1.40a
Cacl ₂ 3 hours	1.33a	1.09a	2.42a	0.71ab	1.37ab
AS12 hours	1.04b	0.87b	1.93b	0.62bc	1.23ab
Kcl 6 hours	1.11b	0.88b	1.99b	0.54bc	1.22ab
H ₂ O 12 hours	1.32a	1.11a	2.43a	0.84a	1.43a
Control	1.15b	0.90b	2.06b	0.49c	1.05b
E9	1.12b	0.92a	2.05b	0.65a	1.36a
E10	1.20a	0.96a	2.16a	0.68a	1.28a
khomain	1.18a	0.94a	2.13ab	0.59a	1.29a

Means with similar letters in each column are not significantly different according to Duncan's multiple range tests at the $P < 0.05$ level.

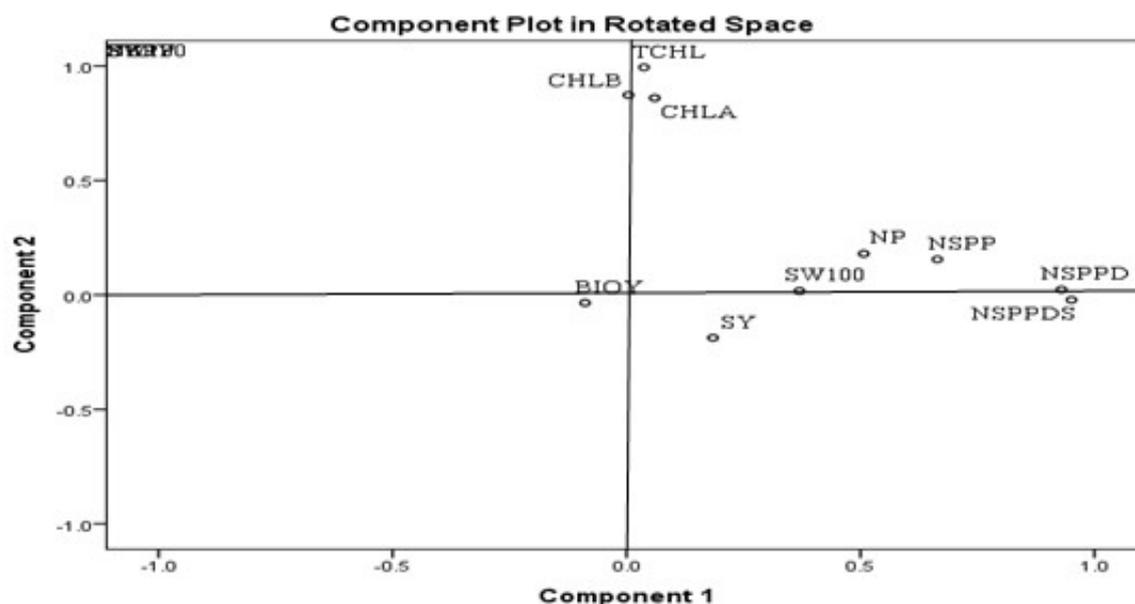
Table 6: Eigen values, variation explained (%), cumulative variance (%) and total variance explained of the principal components based on correlation matrix of yield and yield components

Component	Eigenvalues	Variance (%)	
		Individual	Cumulative
PC1	5.771	41.220	41.220
PC2	2.332	16.657	57.877
PC3	1.528	10.915	68.792
PC4	1.053	7.524	76.316
PC5	0.919	6.562	82.878
PC6	0.739	5.280	88.158
PC7	0.648	4.627	92.785
PC8	0.178	1.269	99.453
PC9	0.057	0.408	99.861
PC10	0.012	0.087	100

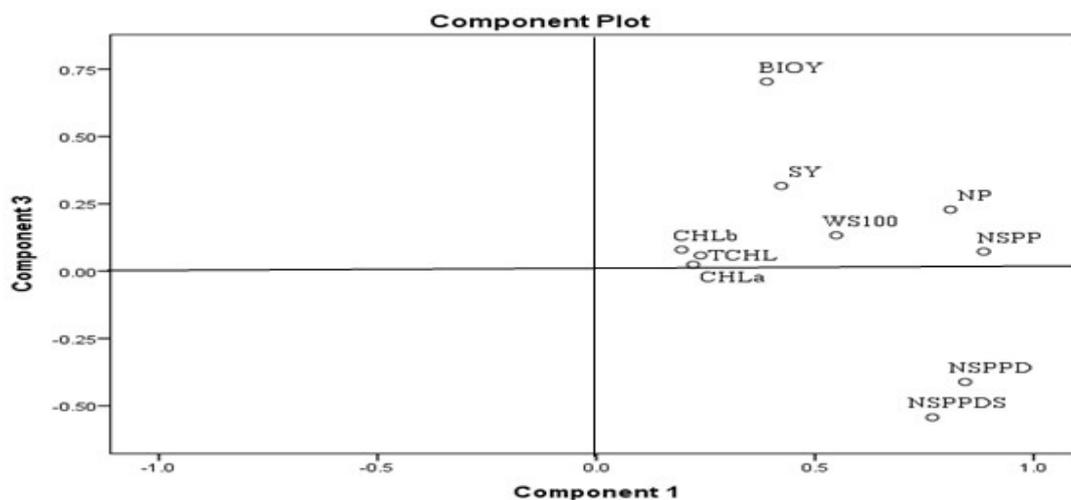
Table 7: Coefficients of determination of the first three principal components related to the studied traits

Trait	Component		
	PC1	PC2	PC3
Seed yield (SY)	.089	-.052	.292
Biological yield (BY)	.052	.141	.404
100 Seed weight (100SW)	-.010	.022	.313

Number of seeds per plant (NSPP)	.142	-.011	.090
Number of seeds per pod (NSPPd)	.146	.126	-.166
Number of seeds per pod subsidiary (NSPPds)	.135	.096	-.187
Number of pods (NP)	.126	-.051	.161
Chlorophyll a (CHLa)	-.085	.303	-.013
Chlorophyll b (CHLb)	-.071	.322	.003
Total chlorophyll (TCHL)	-.089	.359	-.003



Figures 1- Loading plots of PC2 and PC1 in rotated space



Figures 2- Loading plot of PC3 and PC1 in rotated space

Table 8: Correlation of yield and yield components

Trait	Seed yield	Biological yield	100 seed weight (gr)	Number of seeds per plant	Number of seeds per pod	Number of seeds per pod subsidiary	Number of pods per plant	Chlorophyll a	Chlorophyll b	Total chlorophyll
Seed yield	1									
Biological yield	0.23	1								
100 Seed weight (gr)	0.14	0.13	1							
Number of seeds per plant	0.34**	0.28*	0.07	1						
Number of seeds per pod	0.27*	0.18	0.01	0.65**	1					
Number of seeds per pod subsidiary	0.21	0.05	0.05	0.59**	0.91**	1				
Number of pods	0.33**	0.32**	0.05	0.96**	0.48**	0.41**	1			
Chlorophyll a	0.36**	0.10	0.06	0.34**	0.18	-0.24	0.36**	1		
Chlorophyll b	0.20	0.02	0.001	0.31*	0.17	-0.16	0.33**	0.52**	1	
Total chlorophyll	0.32*	0.07	0.03	0.37**	-0.20	-0.23	0.39**	0.86**	0.88**	1

* and **, significant at 0.01 and 0.05 probability level, respectively

4. DISCUSSION AND CONCLUSION

The results showed that priming treatments improved yield and plant growth. Priming increases antioxidant enzymes such as glutathione and ascorbate which lipid peroxidation activity decreased during germination and caused accelerated germination and increased the percentage resulting in the better and earlier establishment of seedlings. Considering the seeds germinating faster and their seedlings earlier appearance on top of the soil, longer photosynthetic period and more chance of production. In addition, priming can improve yield components such as the number of pods per plant and the economic yield. Seed priming in plants increase the total chlorophyll contents and the rate of photosynthesis and ultimately improve the biomass and yield. The results of principle component analysis have also showed that

indirect selection via number of seeds per plant and seed weight, which has higher heritability relative to seed yield is emphasized in this study for genetic improvement of plant yield.

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