

Effect of water supply on seed quality development in common bean (*Phaseolus vulgaris* var.)

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Abstract

In order to determine the best developmental stage of three common bean cultivars (Talash, COS16 and Khomain) at which maximum seed quality is attained under different irrigation regimes (I₁-irrigation after 60 mm, I₂-irrigation after 80 mm and I₃-irrigation after 100 mm evaporation from class A pan), a split plot experiment (using R.C.B. design) with 3 replications was conducted in 2004 at the Research Farm of the Faculty of Agriculture, Tabriz University, Tabriz, Iran. Seeds were harvested at five day intervals in nine stages. Analysis of variance of the data indicated that maximum seed weight, percentages of viable seeds and normal seedlings, seedling dry weight and minimum electrical conductivity of seeds were not significantly different among seeds produced under different irrigation conditions. However, maximum seed weight and minimum electrical conductivity were significantly affected by the cultivars. Maximum seed weight of Khomain was significantly higher than that of Talash and COS16. The lowest and the highest minimum electrical conductivity were obtained for Khomain and Talash, respectively, but this was not significantly different between Khomain and COS16. Changes in seed quality during development and maturity showed that mass maturity and maximum seed vigor under I₃ occurred earlier, compared to other two irrigation regimes. Mass maturity under I₁ and I₂ achieved at about 1270 degree-days after sowing for Talash and 1210 degree-days after sowing for COS16 and Khomain. Mass maturity of all cultivars under I₃ occurred at about 1160 degree-days after sowing. Maximum quality of common bean seeds was attained some times after mass maturity, when seed moisture content was about 16-25%. Seed vigor of all treatments was reduced, as harvests delayed. Therefore, seed quality of pinto bean cultivars under different irrigation regimes could be improved, if seeds harvested slightly after mass maturity.

Keywords: Common bean; Mass maturity; Seed quality; Seed viability; Seed vigor; Water supply

Introduction

High quality seed lots may improve crop yield in two ways: first because seedling emergence from the seedbed is rapid and uniform, leading to the production of vigorous plants, and second because percentage seedling emergence is high, so optimum plant population density could be achieved under a wide range of environmental conditions

(Ghassemi-Golezani, 1992). These are the main reasons for farmers, who are interested to buy and cultivate vigorous seeds. Thus, production of high quality seeds is an important strategy for seed producers.

According to Harrington (1972) maximum seed quality is achieved at the end of seed filling period, which is previously termed physiological maturity (Shaw and Loomis, 1950). Thereafter seeds begin to age, losing viability and vigor. In contrast, many reports on various crops suggested that maximum quality of seeds were attained some time after the end of seed filling (Pieta Filho and Ellis, 1991; Ellis and Pieta Filho, 1992; Demir and Ellis, 1992, 1993; Sanhewe et al., 1996). Therefore, Ellis and Pita Filho (1992) suggested that the term physiological maturity is misleading to the seed physiologists to describe the end of seed filling period and that the term mass maturity is preferable.

Since in many agricultural areas of west Asia water resources are limited, the question is: how is it possible to produce high quality crop seeds in this region? Ghassemi-Golezani et al. (1997) found that sever water deficit (irrigation after 180mm evaporation from class A pan) reduced seed yield of maize and sorghum by 44% and 27%, respectively. However, there was no significant effect of water limitation on seed quality as measured by standard germination, accelerated aging, electrical conductivity and coefficient of velocity of germination. Similarly, Vieira et al. (1992) reported that drought stress had no significant effect on soybean seed germination and vigor. In contrast, Zehtab-Salmasi et al. (2006) showed that water deficit during grain filling led to significant reduction in seed quality of dill.

Although few crops such as wheat, barley, chickpea and lentil are somewhat drought tolerant, but many other crops are sensitive to water deficit. Common bean is the most important food legume which is sensitive to drought stress (Acosta-Gallegos and Adams, 1991; Ramirez-Vallejo and Kelly, 1998). A moderate water stress has reduced common bean yield by 41% (Foster et al., 1995). However, we did not find any report on the effect of water limitation on seed quality of common bean. Therefore, the objective of this research is to determine the best developmental stage of common bean cultivars under well and limited irrigation conditions at which maximum seed quality is attained.

Materials and Methods

A split plot experiment (using R.C.B. design) with 3 replications was conducted in 2004 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Tabriz, Iran (Latitude 38° 05' N, Longitude 46° 17' E, Altitude 1360 m above sea level). The climate is characterized by mean annual precipitation of 245.75mm per year, mean annual temperature of 10 °C, annual maximum temperature of 16.6 °C and mean annual minimum temperature of 4.2 °C. Irrigation regimes (I₁, I₂ and I₃: irrigation after 60, 80 and 100 mm evaporation from class A pan, respectively) were located in main plots and cultivars (Talash, COS16 and Khomain) were allocated to sub plots.

Seeds of common bean cultivars were treated with 2g/kg Mancozeb and then were sown by hand on 24 May 2004 in 5 cm depth of sandy loam soil. At the same time, plots were fertilized with 100kg/ha⁻¹ Ammonium Phosphate. Each plot consisted of 12 rows of 6m length; spaced 25cm apart. All plots were irrigated immediately after sowing, but

subsequent irrigations were carried out according to the treatments. Hand weeding of the experimental area was done as and when required.

After seed formation, plants of 0.6 m² from each plot were harvested at five day intervals in nine stages. Then seeds were detached from the pods and seed moisture content was determined in accordance with ISTA rules (1985). Subsequently, seeds were ambient air dried and 1000 seed weight of each sample was determined. Seed samples within separate sealed bags were then placed in a refrigerator at 3-5 °C.

Seed quality tests were carried out at the Seed Technology Laboratory of Tabriz University. Four replicates of 10 seeds from each sample were tested for germination in sterilized Petri dishes containing two moist filter papers. These Petri dishes were incubated at 20±1 °C for 10 days. At the end of each test, numbers of normal and abnormal seedlings were counted (ISTA, 2005) and percentages of viability and germination were calculated. Normal seedlings were then dried in an oven at 80 °C for 24 hours (Perry, 1977) and mean seedling dry weight (SDW) for each replicate was determined.

Two replicates of 50 seeds from each sample were weighed (SW₁ and SW₂) and then seeds of each replicate immersed in 250 ml deionized water in a container at 20 °C for 24 hours. The seed-steep water was then gently decanted and EC was measured, using an EC meter (EC₁ and EC₂). Following equation was applied to calculate conductivity per gram of seed weight for each sample (Powell et al., 1984).

$$EC (\mu\text{s}/\text{cm}/\text{g}) = [(EC_1/SW_1) + (EC_2/SW_2)]/2$$

The accumulated growth degree-days (GDD) were computed from planting time by a base temperature (T_b) of 10 °C (Russell et al., 1984).

$$GDD = \sum (T_{\text{max}} + T_{\text{min}}) / 2 - T_b$$

Where T_{max} and T_{min} are maximum and minimum air temperatures, respectively. Analysis of variance and comparison of means at P≤0.05 were performed, using SAS (1996) software. Excel software was used to draw figures.

Results

Changes in seed weight of common bean cultivars during development and maturity (Figure 1) showed that grain weight of Talash, COS16 and Khomain under I₁ and I₂ considerably increased, with increasing GDD up to 1270, 1210 and 1210, respectively. Thereafter, changes in seed weight were negligible. Thus, mass maturity of common bean cultivars under well-watering (I₁) and mild water stress (I₂) was achieved at 1210-1270 GDD, depending on cultivar. However, mass maturity of all three cultivars under I₃ (irrigation after 100 mm evaporation) was occurred at about 1160 GDD (Figure 1).

Seed viability of common bean cultivars at early stages of seed growth was very low, but it was increased with enhancing seed development (Figure 2). This improvement continued until maximum seed viability was attained. Then, percentage of viable seeds started to decrease. Maximum seed viability under I₁, I₂ and I₃ was obtained at 1330, 1320 and 1280 GDD for Talash, at 1390, 1310 and 1330 GDD for COS16 and at 1330, 1380 and 1280 GDD for Khomain, respectively (Figure 2). In general, maximum seed viability under limited irrigation (I₃) achieved earlier than that under well irrigation (I₁).

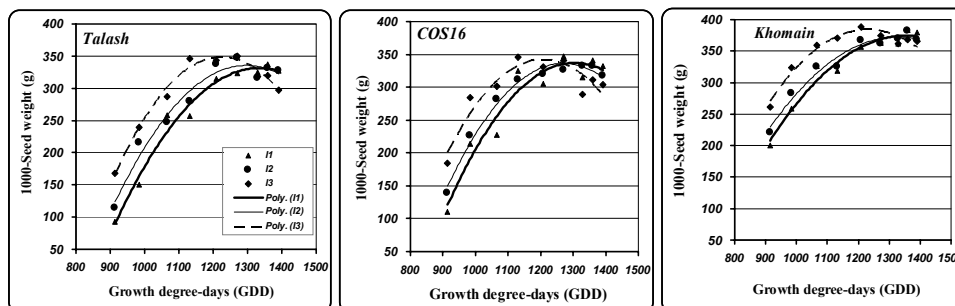


Figure 1. Changes in thousand seeds weight of three pinto bean cultivars at different stages of maturity under different irrigation conditions I₁, I₂ and I₃: irrigation after 60, 80 and 100 mm evaporation from class A pan, respectively.

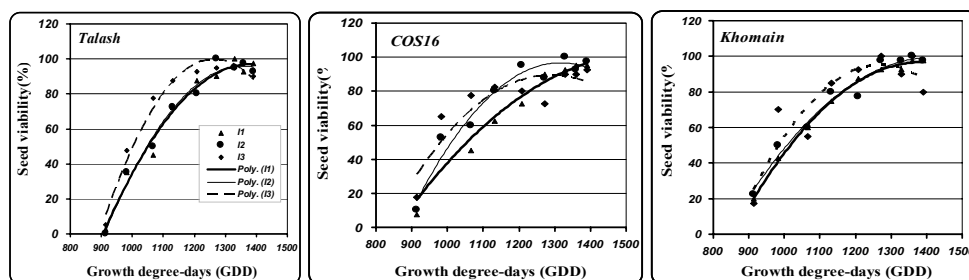


Figure 2. Changes in seed viability of three pinto bean cultivars at different stages of maturity under different irrigation conditions.

Changes in seed germination of the cultivars were similar to that of seed viability, with the exception of some differences in growing degree days at which maximum germination percentages were attained (Figure 3). Maximum seed germination for Talash, COS16 and Khomai was occurred at 1300, 1310 and 1290 GDD under I₁, at 1290, 1290 and 1370 GDD under I₂ and at 1260, 1300 and 1240 GDD under I₃, respectively (Figure 3).

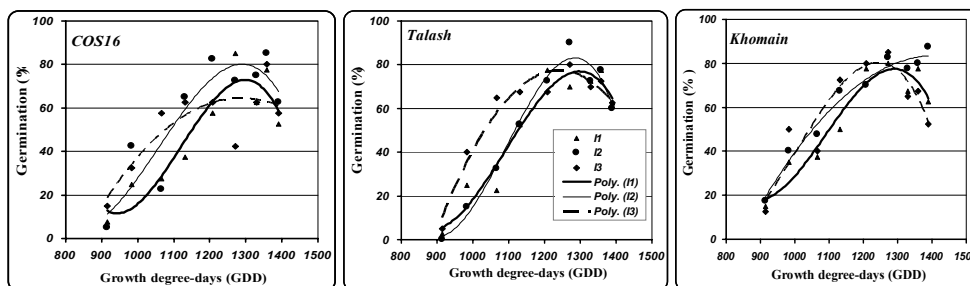


Figure 3. Changes in seed germination of three pinto bean cultivars at different stages of maturity under different irrigation conditions.

Electrical conductivity (EC) of seed leachates for all common bean cultivars at early stages of seed development under different irrigation regimes was very high, but sharply decreased with increasing GDD up to about 1270. Thereafter, little changes in EC of seed leachates were observed (Figure 4).

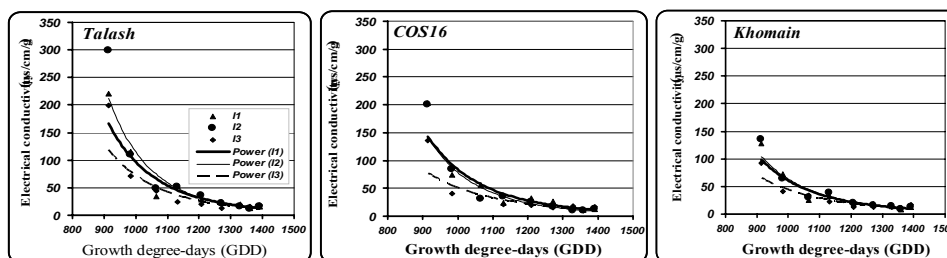


Figure 4. Changes in electrical conductivity of three pinto bean cultivars at different stages of maturity under different irrigation conditions.

Analysis of variance of the data for maximum seed weight and quality parameters showed that only maximum seed weight and minimum EC of seed leachates were significantly affected by cultivar ($P \leq 0.05$). Khomain had the largest seeds and the lowest solute leakage, compared to other cultivars (Table 1). However, the effect of water supply on maximum seed viability and germination percentages and minimum EC of seed steep water were not significant ($P > 0.05$).

Table 1. Comparison of means of maximum thousand seed weight of three pinto bean cultivars under different irrigation regimes.

Cultivar	1000-seed Weight (g)	Electrical conductivity ($\mu\text{s}/\text{cm}/\text{g}$)
Talash	344.667 b	12.1067 a
COS16	339.822 b	10.2792 b
Khomain	384.533 a	9.8983 b

Different letters indicating significant difference at $P \leq 0.05$.

Discussion

Seed filling rate of common bean cultivars increased, but seed filling duration decreased, as water deficit severed (Figure 1). As a consequence, maximum seed dry weight (mass maturity) under water stress attained earlier than that under well-watering. Stimulation of seed maturity under water limitation is also reported in lentil (Erskine and Ashkar, 1993), soybean (Desclaux and Roumet, 1996; Vieira et al., 1992), wheat (Li et al., 2000; Oosterhuis and Cartwright, 1983), barley (Samarah, 2005), chickpea (Silim and Saxena, 1993) and maize (Ne Smith and Ritchie, 1992).

Khomain produced larger and more vigorous seeds, compared to other cultivars (Table 1). Different sizes of seeds having different levels of food storage may be the important factor which influences seed vigor (Perry, 1980). Singh et al. (1972) reported that large

seeds of soybean had greater supply of stored energy to support early seedling growth. Therefore, seed size is considered to be a significant factor only during the early stages of growth (Ghassemi-Golezani, 1992).

Maximum seed quality as measured by seed viability and germination percentages was obtained 20–160 GDD after mass maturity, depending on cultivar and irrigation regime (Figures 1, 2 and 3). This was achieved 60–180 GDD after mass maturity, when seed quality was evaluated by electro-conductivity test (Figure 4). Seed moisture content at these stages was 16–25%, varying among cultivars and irrigation treatments. These results contradict the hypothesis that seeds attain maximum quality at the end of seed filling phase (Harrington, 1972), but compatible with the results reported for cereals (Pieta Filho and Ellis, 1991; Ellis and Pieta Filho, 1992), grain legumes (Sanhewe and Ellis, 1996) and vegetables (Demir and Ellis, 1991, 1993; Demir and Samit, 2001).

Water supply had no significant effect on maximum seed vigor of common bean cultivars, as determined by minimum electrical conductivity of seed leachates (Figure 4). This result strongly supported by previous reports on maize and sorghum (Ghassemi-golezani et al., 1997) and soybean (Vieira et al., 1992). In contrast, stage of maturity at harvest influenced seed quality under both well and limited irrigation conditions. Low quality of seeds at early harvests was due to immaturity. However, seed quality increased with progressing seed development, until maximum quality was achieved (Figures 2, 3 and 4). Seed development is characterized by numerous cell divisions and differentiation of organs, acquisition of assimilates from the mother plant and consequently a substantial increase in seed weight. Deduction of seed quality at delayed harvests is attributed to the beginning of seed ageing on parent plant (Ellis and Pieta Filho, 1992).

Conclusion

It is conceivable to produce high quality seeds of common bean cultivars under both well and limited irrigation conditions, if plants are harvested some times after the end of seed filling phase (mass maturity) and seed moisture content is about 16–25%. Early and delayed harvests could lead to the production of low quality seeds.

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