

correlated with basal root weight ( $r=.88$ ), basal root diameter ( $r=.85$ ), and with basal root number ( $r=.67$ ). Plants with larger hypocotyl diameter at the basal region, in wider within-row spacings, resulted in a larger diameter, a higher number, and a higher dry weight accumulation of basal roots. Stoffella et al. (7) concluded that basal roots in black beans are of importance to reducing lodging.

No differences in seed yield occurred between cultivars although a higher biological yield and lower HI for 'Redkote' were noted (Table 3). Seed yield from 15 cm within-row spacing was significantly greater than from 10 or 20 cm, however, not significantly different from 5 cm. Kueneman (4) reported nonsignificant dry bean yield differences between 5 and 10 cm within-row spacing regardless of plant type. No differences in biological yield or HI were measured among within-row spacings.

A significant cultivar  $\times$  spacing interaction occurred for only total root weight. 'Redkote' had a larger increase in total root weight between 15 and 20 cm within-row spacings than 'Redcloud', thereby

resulting in a significant cultivar  $\times$  spacing interaction. Uprooting resistance did not dramatically increase between 15 and 20 cm spacings for 'Redkote'. This resulted in a nonsignificant response for uprooting resistance between the 15 and 20 cm spacings. Since uprooting resistance responded similarly for the 2 cultivars at the other within-row spacings, the main effect for uprooting resistance due to cultivar differences was nonsignificant. Other first and second order interactions were significant for most root morphological characteristics.

Salih (5) reported that root weight in soybeans increased as within-row spacing increased. Similarly we found that root weight and other root morphological characteristics increased as within-row spacings increased. A larger root biomass production of individual plants could contribute to increases in water and nutrient uptake and lodging resistance in dry beans. Further investigations are needed to determine if these results exist at narrower row widths, where seed yields are generally higher, particularly during environmental stress conditions.

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# Rate of Water Uptake and Sites of Water Entry in Seeds of Different Cultivars of Dry Bean<sup>1</sup>

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**Abstract.** Variations occurred in the rate of water uptake of seeds of different dry bean cultivars (*Phaseolus vulgaris* L.). 'Pinto UI 111' had a higher water uptake by 24 hours than the other 6 cultivars. The micropyle was the main site for water entry in white-seeded 'Great Northern' and it is inferred that the raphe and or hilum areas were mainly involved in water uptake in 'Pinto UI 111'. No water uptake through the seed coat of seeds of 7 cultivars occurred by 2, 4, or 8 hours and only a small amount by 24 hours, except 'GN Star' where no water uptake was noted indicating that it had an impermeable seed coat during that period.

Seed hardness causes reduced or delayed germination of bean seeds and it

degrades the texture of processed bean products. This is due to reduced or complete lack of imbibition of water by the hard seeds. Genetic variations for this trait were first reported by Lebedeff (4, 5). The barrier to water intake is a critical regulating element and research has been conducted to determine the relative importance of various areas of the seed in their hindrance to water uptake by the bean seeds (3, 8, 9, 11) and on the relation of water uptake and transverse cotyledon cracking (1, 6, 7). Watson (10) dismissed the role of structural differences in the testa in relation to water permeability. Kyle and Randall (3) reported that the micropyle was the primary area of water entry in Great Northern (GN) beans while the raphe and hilum areas

were important sites of water entry in a Red Mexican dry bean cultivar.

Since there are conflicts in the literature on the nature of seed hardness in beans and only one seed stock of GN dry beans was used earlier by Kyle and Randall (3), the objective of this study was to determine the rate of water uptake in various GN cultivars along with 'Bulgarian White' and 'Pinto UI 111'. The relative importance of the micropyle and seed coat in water uptake in relation to seed hardness in these cultivars was also investigated.

The dry bean cultivars used in the investigations were 'GN Emerson', 'GN UI 59', 'Bulgarian White', 'GN Star', 'Pinto UI 111', 'GN 1140' and 'GN D-88'. The cultivars were planted in single row plots, 30 seeds per 5 m row length, rows spaced 55 cm apart, in a randomized complete block design with 3 replications, in the field at Scottsbluff, Nebraska, on June 6, 1979.

Single plants were harvested in September at physiological maturity (most pods brown and some yellow), allowed to dry in paper bags and then thrashed by hand. Twenty seeds per cultivar from each replicate were weighed and soaked in distilled water (22°C) for 24 hr (method 1). Seeds were weighed after 1, 2, 4, 8 and 24 hr of soaking. The amount of water imbibed was calculated by subtracting the original weight from the latter weights. The initial seed moisture content,  $8 \pm 0.1\%$ , was determined by drying sub-samples at 68°C for 48 hr.

Sites of water entry into the bean seeds were also investigated. In one treatment,

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5 seeds of each cultivar from each replicate were sealed with a layer of white silicone rubber leaving the micropyle area open (method 2). In the other treatment, 5 seeds from each replicate were sealed along the micropyle, hilum and raphe areas, leaving the seed coat area free from treatment (method 3).

After sealing, the samples were weighed. Then the seeds were soaked in distilled water (22°C) and weighed after 1, 2, 4, 8 and 24 hr.

Seeds of the 7 untreated cultivars had imbibed only small amounts of water after 4 hr (Fig. 1). Similar results occurred when water uptake was allowed only through the micropyle (Fig. 1). At 8 and 24 hr the cultivars in the 2 groups (treated and untreated) exhibited differences in percent water uptake of untreated seed versus treated seed (with open micropyle). A significant F value ( $P < 5\%$ ) was calculated for method 1 vs. method 2 for 'GN UI 59', 'GN Star', 'Pinto UI 111', 'GN 1140', 'GN D-88' at 8 hours and for 'Pinto UI 111' at 24 hours. Covering the hilum, raphe and seed coat with silicone, resulted in significant reduction of water uptake of 'Pinto UI 111' seeds at 24 hr in comparison to all of the white-seeded cultivars (Fig. 1). The white-seeded cultivars showed a high water uptake by 24 hr and no significant differences between them were noted (Fig. 1). Seeds of the white-seed cultivars had imbibed about the same amount of water under method 1 and 2 by 24 hr. A non-significant F value ( $P > 5\%$ ) was found for method 1 vs. method 2 for the white-seeded types. At 24 hours of soaking, 'Pinto UI 111' had the highest water uptake in untreated seeds in comparison with all of the white seeded cultivars, except 'GN Emerson' (Fig. 1). These results indicated that the micropyle was important for water entry in the white seeded cultivars.'

When the micropyle, hilum, and raphe were sealed (method 3) no water uptake by the seeds was detected by the end of 2, 4, and 8 hr but a small amount of water uptake was observed at 24 hr. 'GN Star' showed no water uptake by 24 hr indicating an impermeable seed coat during this entire period. There was no significant difference ( $P > 5\%$ ) in water uptake (9 to 32%) through the seed coat of the other cultivars.

All seed samples failed to show any water uptake through the seed coat for the first 8 hr. This is in contrast to seed coat water absorption data reported by Wyatt (11). However, by 24 hr of seed soaking a

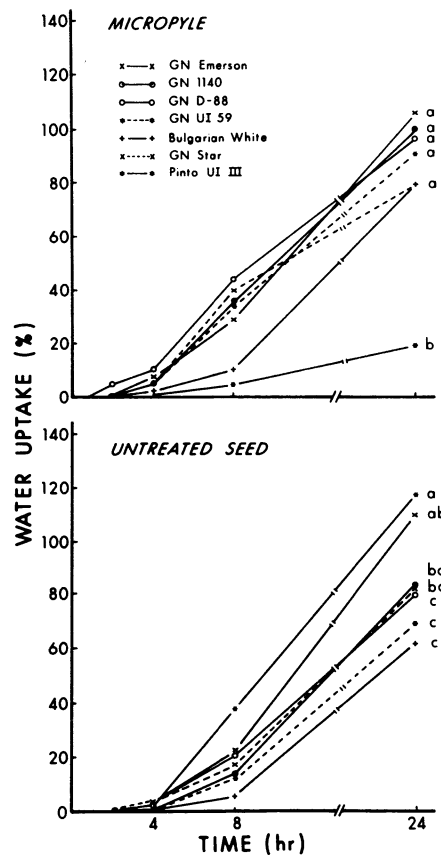


Fig. 1. Rate of water uptake of untreated seed, and through the micropyle of seed of dry bean cultivars. Mean separations, at 24 hr using Duncan's multiple range test within graphs, 5% level.

small amount of water uptake was observed by us except in the case of 'GN Star' which did not absorb any water. Wyatt (11) found seed coat thickness of 4 near-isogenic lines of snap bean to be negatively correlated with rate of osmosis through isolated seed coats (with no cotyledons). No such relationship could be established in the intact seeds (with cotyledons) used here. Seed coat thickness of these cultivars was determined in a separate study (2) and it was observed that 'GN Emerson' had a thick seed coat and high intake of water while 'Pinto UI 111' had a thin seed coat but also a high rate of water imbibition (2).

In the case of 'Pinto UI 111' neither the micropyle nor the seed coat were the main sites for water entry so perhaps water intake occurred through the hilum or raphe or both. Thus, studies need to be

conducted to determine the relative importance of the hilum and raphe in water absorption in 'Pinto UI 111'. The micropyle appears to be the main site of entry of water into Great Northern beans and confirms the findings of Kyle and Randall (3). No genetic variation within Great Northern cultivars was detected by us.

Wyatt (11) suggested that slower absorption of water by colored seeds may permit more uniform swelling of the cotyledons, and thus reducing seed coat and/or cotyledon cracking. The imbibition studies reported here indicated a rapid rate of water uptake by 'Pinto UI 111' which was found by us to be highly resistant to seed coat cracking (2). This is in disagreement with Wyatt's speculation on the association of seed coat cracking resistance and slower water absorption, but perhaps our finding is an exception. Additional studies with more Pinto cultivars would lead to better clarification on this issue.

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