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Analysis of the Effects of Hypogeal and Epigeal Emergence on Seedling Competition in Legumes

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The Edwin P. McCabe Honors Program

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TABLE OF CONTENTS

ABSTRACT

Seedling emergence is either hypogeal or epigeal. In hypogeal emergence the cotyledons remain below the soil surface during seedling development, while in epigeal emergence the cotyledons extend above the soil surface due to elongation of the hypocotyl. Here we examine the effect of seed size, and emergence type, on seedling growth. Six legumes with variation in seed size and either epigeal or hypogeal emergence were grown under dark and light conditions. A competition study was also conducted where a hypogeal and epigeal legume were grown in combination with wheat and ryegrass. Legumes expressing epigeal emergence were cowpea (*Vigna unguiculata)*, mung bean (*Vigna radiata*) and soybean (*Glycine max* Merr.), while Austrian winter pea (*Pisum sativum* var. *arvense* (L.) Poir), field pea (*Pisum arvense)* and lentil (*Lens culinaris*) expressed hypogeal emergence. In the dark growth study, seed size did not have a direct effect on growth, but there was a correlation with the heavier seeded species having heavier seedlings. Soybean had the largest seedlings under both dark and light conditions. Wheat and ryegrass competition reduced both Austrian winter pea and soybean growth. However, the cool air-temperature during the study may have favored the growth of Austrian winter pea, a cool-season legume. Soybean, a warm-season legume, seedling development may have been limited by the cool-temperature. We could not separate hypogeal or epigeal emergence types as to seedling growth or competitiveness. However, seed size did have a direct effect on seedling size, regardless of emergence type.

INTRODUCTION

Does seed size or weight affect germination or seedling growth rate or seedling size? Here we compare legume seed of various sizes and emergence type to examine this question. Germination is the beginning of an active growth by the seed embryo resulting in the rupture of the seed coat and emergence of a new plant. Although germination does not depend on nutrient availability in the soil due to energy reserves in the cotyledons, germination and development does depend on temperature, moisture, planting depth, seed quality, and soil compaction at planting (Pepper 1998). Because of this, seed size should have a limited impact on germination.

Across a range of seed sizes, minor effects on emergence have been reported and soybean seeds of extremely small size, which normally do not make their way into the market, maybe reduced in emergence when planted at a normal soil depth of 25 to 50 mm. Final difference in plant sizes, which might result from planting seed of different sizes, does not suggest any problems with using small seed (Pepper 1998).

Soybean seed size is not directly correlated with yield potential as several smaller-seeded varieties have high yield records and while seed may have lower yields. Larger seeded-varieties could encounter more difficulty in emergence than smaller seeded varieties, particularly under cool temperature soil conditions. Research in Mississippi indicated small-and medium-sized seed gave more rapid emergence and greater early root development than large seeds (Svec 1997).

In a study by Smart and Moser (1999), seed size was associated with early seedling vigor (i.e., germination rate, emergence rate, and growth) in grasses. Seed size differences in switchgrass (*Panicum virgatum* L.) proved to produce only slight differences in morphological development of shoot and root systems, leaf area, shoot weight, and adventitious root weight from seedling emergence to 6 weeks of growth. Roots formed more quickly on seedlings from heavier than lighter seed, but the advantage to seedling establishment was minimal.

Jarado and Westoby (1992) reported that seedlings of heavier-seed species tend to survive longer than seedlings from lighter-seeded species when grown in the absence of nutrients other than those in the seed. Seedlings from heavier seeded species had a lower relative growth rate than that of lighter seeded species during the first 10 days after germination. However, seed size was more important than relative growth rate on germination speed in determining seedling size 10 days after seeds were planted.

Leffler and Williams (1983) found that cotton (*Gossypium hirsutum*) seeds of medium density were capable of sustaining growth through a 4-week period and seedling growth was more vigorous than seeds of high or low density. The medium density seeds were not only more efficient in the initial onset of germination, but could also apparently mobilize more reserves to nourish the growth of seedlings. Maturity (density) and seed weight (quantity of available substrate) determined seedling growth rates at optimum temperature.

It has been reported that seed size was related seedling vigor in such crops as soybean [*Glycine max* (L) Merr.], cucumber (*Cucumis sativus* L.) and tomato (*Lycopersicon esculentum* L.). In birdsfoot trefoil (*Lotus corniculatus* L.) and subterranean clover (*Trifolium subterraneaum* L.), large seed size was associated with improved field emergence and first year forage yields. After emergence, subsequent growth differences in birdsfoot trefoil from various seed sizes were related more to photoassimilate partitioning to leaves and initial photosynthetic area than to the amount of seed reserve. In cowpea (*Vigna unguiculata* L.), germination, hypocotyl and shoot length, vigor index, and dry matter production were positively correlated with seed weight. A study on seedling growth and seed size among 20 pigeon pea genotypes showed a positive and essentially linear relationship. It was concluded that selection criteria in pigeon pea should include larger seeds, epigeal emergence and larger unifoliate and trifoliate leaves in order to improve juvenile vigor and crop growth (Brakke and Gardner 1987).

Seed size has been positively correlated with seedling vigor among smaller seed species, but for cereal crops and larger seeded species there is no consistent relationship between seed size and vigor over the normal range of seed sizes sold. High seed density has been associated with seedling vigor in wheat, cotton, and wild rice (*Zizania palustris* L.) (Cardwell 1984).

Seedling emergence is either epigeal or hypogeal. Epigeal emergence is when the hypocotyl is active and pulls the cotyledons above ground (Nelson and Larson 1984). In hypogeal emergence, the hypocotyl remains inactive and the cotyledons remain below ground. Epigeal emerging plants have advantage over hypocotyl emerging plants in that the cotyledons can be photosynthetic after emergence providing additional energy for seedling development. In contrast, hypogeal emerging seedlings have an advantage in that stored energy supply remains below ground and can provide regrowth if the tops are removed by insects, frost, or other factors.

Legumes can be used as full-season crops, as double crops planted before or after a cash crop to provide nutrients and organic matter, or living mulch planted between crop rows to provide weed control. Legumes can be planted any time from early spring through fall. However, best growth for a full season crop usually occurs when planted in early spring (March-April). For fall planting, early August to early September is optimum planting time. Planting later than mid-September may reduce plant growth and decrease cold tolerance of over wintered crops. Cold tolerant legumes can be grown through the winter months to reduce soil erosion. It is important to select a legume that is competitive, as well as tolerant to cool temperatures (Thornton et al 2002).

Because plants need sunlight, water and nutrients for growth, there has been an increase in interest concerning the effect of weed competition on crop growth and yield over the years (Bewley and Black 1994). Since single weed species are uncommon in production agriculture, and competitive effects of multispecies weeds populations at low densities are also important (Toler et al 1996). The ability to predict the effect of two or more weeds on crop yield is beneficial. It was reported in a study by Weaver (2001) that lamb's quarters caused a 14 to16% decrease in soybean yield at low weed density, and maximum crop yield loss was estimated to be 60 to75% at a high weed density. Also in this study, the estimated maximum yield loss caused by common ragweed at high density was 65 to 70% and green foxtail attributed to a high-density loss of about 80%. The time of weed emergence relative to crop emergence has been shown to be critical in determining the outcome of weed competition (Cowan et al 1998). Being able to predict the effect of two or more weeds on crop growth would be beneficial in that it would allow an estimate of the yield. This information is useful in planning management decisions.

In a field trial, it was reported that when wheat and annual ryegrass are grown together, annual ryegrass reduced the capacity of wheat to produce tillers. Also, the addition of annual ryegrass to wheat crop reduced the above ground dry weight of wheat at anthesis and maturity. The report also stated that annual ryegrass when planted at the same time as wheat caused a 50% reduction in dry matter Palta and Peltzer (2001).

To determine the effect of seed size and emergence type on seedling growth, six legumes with variation in seed size and either epigeal or hypogeal emergence were grown under dark and light conditions. Legumes expressing epigeal emergence were cowpea (*Vigna unguiculata)*, mung bean (*Vigna radiata*) and soybean (*Glycine max* Merr.), while Austrian winter pea (*Pisum sativum* var. *arvense* (L.) Poir), field pea (*Pisum arvense)* and lentil (*Lens culinaris*) expressed hypogeal emergence. The objective of this study is to determine the relation between dark seed growth and/or cotyledon weight, to determine growth rate of the six forages, and competitiveness difference in emergence type.

MATERIALS AND METHODS

Seed were obtained from commercial sources. The hundred-seed weight was for each species by determining the air-dried weight of 100 seeds (Table 1). In all the seedling growth studies the seed were surface sterilized in 50 ml of a 0.06% Clorox solution for 15 min, rinsed three times with distilled water, and air-dried.

Dark-Seedling Growth Study:

Seedling pouches (177 mm X 225 mm) were constructed by lining sandwich bags with two paper towels and a sheet of blotter paper for support. A piece of wire was taped to the back of each pouch to serve as a hanger and the pouches were suspended in a plastic pan. Four seeds were placed in the pouch and 20mL of a 2mM $CaSO_4$ solution was added. Some legume seed are calcium deficient and the calcium solution was added to insure adequate seedling development.[1] The planted pouches were placed in a dark growth chamber. Chamber temperature averaged 20°C. Seedlings were watered as needed. Seedlings were harvested at 6, 13 and 22 days after planting (DAP).

Table 1. One-hundred-seed weight.

Species	Seed weight
	(mg/100)
Austrian winter pea	13353
Cowpea	19284
Field pea	12543
Lentil	5059
Mung bean	6265
Soybean, Black	23829
Soybean, Green	20829

The experiment was arranged as in random block design with six species and three replications for a total of 18 individual observations per species per harvest. The study was repeated and harvests were made on 3, 7, 14 and 21 DAP. The 3-day harvest was used to determine embryo, cotyledon, and seed coat weights. Data for both studies were pooled for statistical analysis.

[1] Personal communication: Robert E. Hoagland, USDA-ARS, Weed Research Unit, Stoneville, MS.

Light-Seedling Growth:

Two experiments were conducted on seedling growth in the light. In the first experiment, seedlings were grown under laboratory conditions under a light bench using the same procedures given above for the dark-growth study. The lights were on a 12-h photoperiod and supplied a light intensity of 400 micro-Einsteins. Seedlings were watered as necessary and harvests were 7, 14, 22 and 29 days after planting. Data were analyzed as previously described.

The second experiment was conducted in a walk-in growth chamber. The chamber was set at 27°C day/ 16°C night with a 12-h photoperiod providing a light intensity of 175 micro-Einsteins during the day. Seed were planted in cone-tainers (110 cm^3) filled with commercial potting soil. Each species was sown at a 22 mm-soil depth. After emergence, seedlings were thinned to one plant per cone-tainer and watered as necessary. Seedlings were harvested 6, 14, 21 and 28 DAP. Three seedlings per species were randomly selected at each harvest, and separated into root, stem, and leaves. Dry weight was determined by oven-drying the plant material at 75° C for 24 h.

Seedling Competition Study:

Based on previous germination and seedling growth experiments, Austrian winter pea, soybean, winter wheat and Marshall Italian ryegrass were selected for the competition study. Austrian winter pea (hypogeal) and soybean (epigeal) were the crop (forage) species, while wheat and Italian ryegrass served as the "weed". Seeds were pre-germinated (4 to 5 days) and seedlings transplanted to cone-tainers filled with commercial potting soil. Each forage species was grown alone or in combination with two or four "weeds," either the winter wheat or Italian ryegrass species. For example, one AWP seedling with four two or four ryegrass seedlings was transplanted to a cone-tainer. In each case, the legume seedling was placed in the center of the cone-tainer surrounded by the grass seedlings. The cone-tainers were placed in a growth chamber with the environmental conditions previously described. Seedlings were watered as needed.

At harvest, the seedlings were removed from the cone-tainers and the soil gently washed from the roots. Legume species were separated from the grasses. After shoot and root lengths were measured to the nearest mm, the seedlings were separated into shoots, roots and cotyledons. Grasses from each cone-tainer were pooled, and separated into roots and shoots. Dry weights were determined after oven drying the material at 70°C for 48h.

RESULTS AND DISCUSSION

Dark-Seedling Growth Study:

Data from the dark seedling growth were combined and are presented by harvest (H1, H2, and H3). The 3-DAP harvest for the second study was not included in the analysis, and the embryo and seed coat weights obtained at this harvest are presented in Table 2. Seed coat weight ranged between 75 and 16 mg, while total embryo weight ranged between 50 mg (cowpea) and 19 mg (Austrian winter pea).

Table 2. Seed coat and embryo dry weight.

Species	Embryo

	Seed Coat[1]	Total[1]	Mean
	(mg)		
Austrian Winter Pea	36	19	5
Cowpea	36	50	13
Field pea	71	22	6
Lentil	16	23	6
Mung bean	22	23	6
Soybean	75	35	9

[1] Combined weight of 4 seeds.

There was no apparent relationship between embryo weight and embryo length. Although lentil had one of the longest embryos it was one of the lighter seeds, while cowpea embryo weight was near twice that of mung bean the embryo lengths were similar (Figure 2).

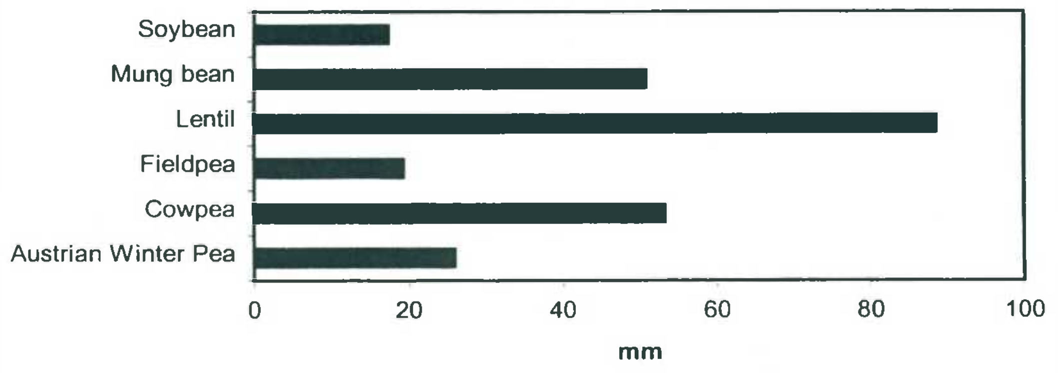

Figure 2: Average Embryo Length

Soybean had the heaviest average cotyledon weight of the epigeal legumes with 207 mg, and field pea had the heaviest cotyledon weight of the hypogeal legumes with 159 mg. Lentil average cotyledon weight was the lightest, which was expected due to its low one hundred seed weight.

Table 3. Cotyledon dry weight.

Harvest	Species					
	-----(mg)-----					
	Austrian winter pea	Cowpea	Field pea	Lentil	Mung bean	Soybean
H1	81	93	60	23	31	207
H2	19	10	4	3	1	98
H3	8	0	0	2	0	58

Combining the total seedling dry weight over both studies, soybean seedlings were the heaviest, followed by cowpea, Austrian winter pea, field pea, mung bean and lentil (Figure 3). The difference between total soybean dry weight and Austrian winter pea and cowpea were significantly different at the 0.05 probability level.

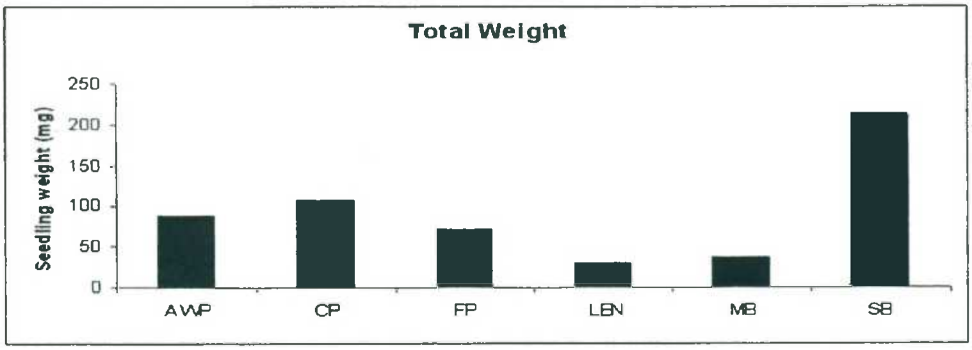

Figure 3. Total dark-growth seedling weight regardless of harvest.

When total seedling dry weight was examined by harvest, each species showed a decrease in dry weight between harvest periods (Figure 4). The greatest loss in seedling dry weight occurred in soybean between H 1 and H2.

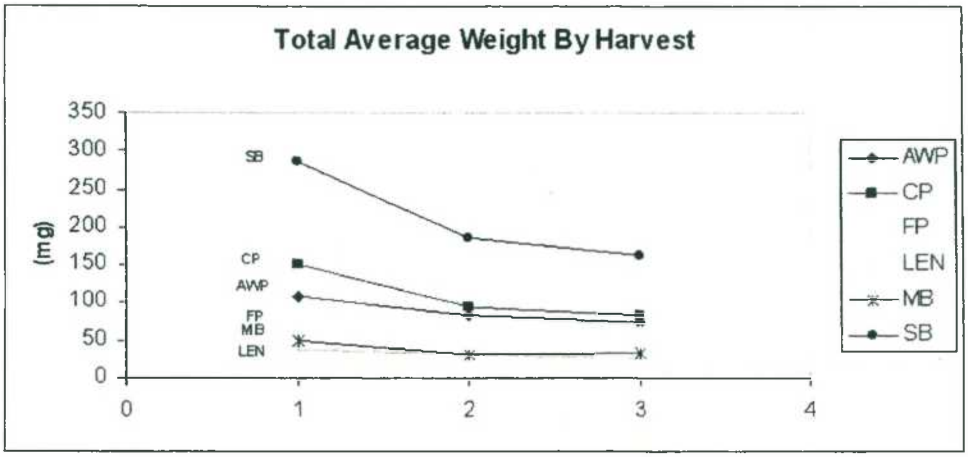

Figure 4. Total seedling dry weight dark-growth by harvest

Also note that the legumes separate in three groups: soybean; cowpea-field pea-Austrian winter pea; and mung bean-lentil. This apparent grouping is a reflection of the total cotyledon dry weight (Figure 5). At H1, the ranking of total cotyledon dry weight from heaviest to lightest was soybean, cowpea, Austrian winter pea, field pea, mung bean and lentil.

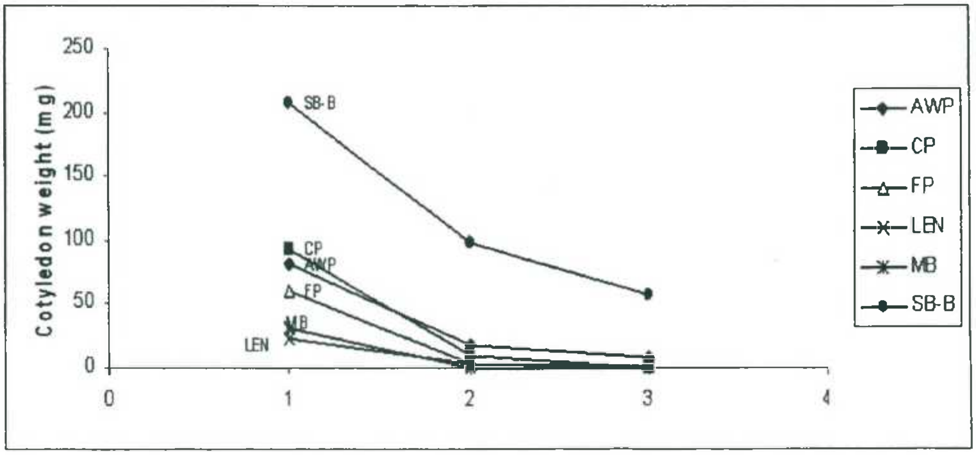

Figure 5. Average cotyledon weight under dark conditions by harvest

The ranking in Figure 5 is reflected in the seed weight data presented in Table 1. The decrease in total dry weight by harvest reflects the decrease in cotyledon dry weight and the partitioning of stored material into root and shoot structures. As cotyledon dry weight decreased (Figure 5) there was an increase in both shoot (Figure 6) and root (Figure 7) dry weight. The increase in soybean shoot dry weight appeared to be linear, while the dry weight of the other legumes increased between H1 and H2, and declined slightly between H2 and H3. There is also an apparent grouping of the legumes: soybean-cowpea; Austrian winter pea-field pea; and lentil-mung bean. The root dry weight displays this same apparent grouping (Figure 7), and in most cases the species increase in dry weight is nearly linear.

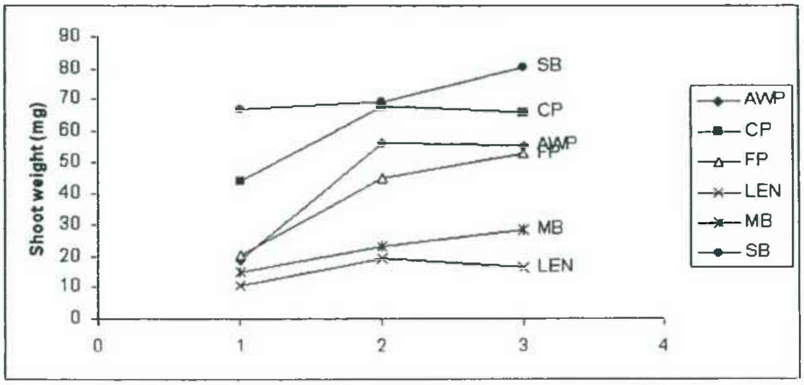

Figure 6. Average shoot dry weight under dark conditions by harvest.

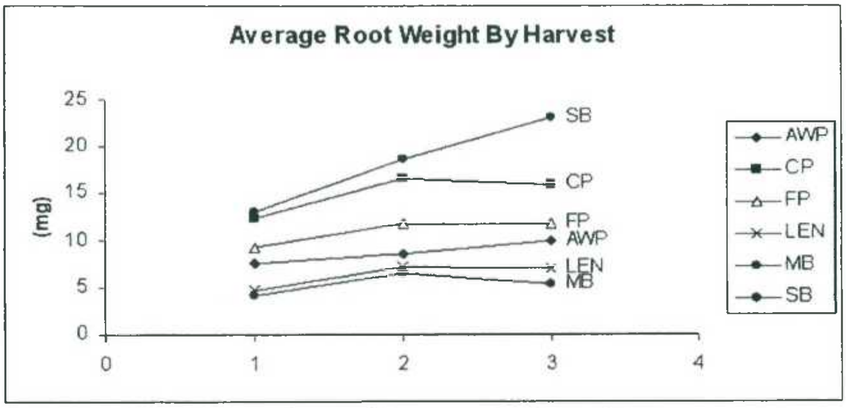

Figure 7. Average root dry weight under dark conditions by harvest

Except for Austrian winter pea, there was no difference among the legumes as to seedling length (Figure 8). Data for root and shoot length showed a similar trend as presented for seedling length (data not presented). At each harvest Austrian winter pea had the longest seedling. This is probably a reflection of the growth habit of this legume. Austrian winter pea tends to "vine"; where as the other legumes tend to have a "bush" appearance. Although there was difference in dark seedling growth among the legumes studied, there was no statistical difference between emergence types. The growth shown is a function of cotyledon reserves, and the partitioning of those reserves into shoot and root material. The larger the seed (cotyledon) is, the greater the potential for dark-seedling growth. However, the difference soybean (hypogeal) and cowpea (epigeal) root and shoot weight were similar, even thought soybean cotyledon weight was greater.

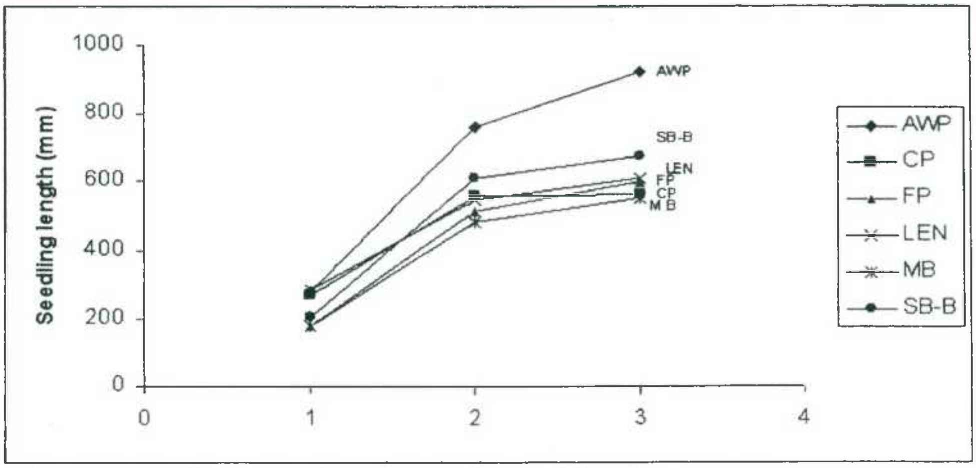

Figure 8. Seedling length under dark condition by harvest.

Light-Growth Study:

Seed Pouches

Soybean had the greatest total dry weight at each harvest and had a final dry weight of 496 mg (Figure 9). Austrian winter pea, field pea, cowpea, mung bean, and lentil each followed with final weights of 328 mg, 275 mg, 237 mg, 177 mg, and 81 mg. With soybean being a broader plant, it is expected to have a heavier seedling weight.

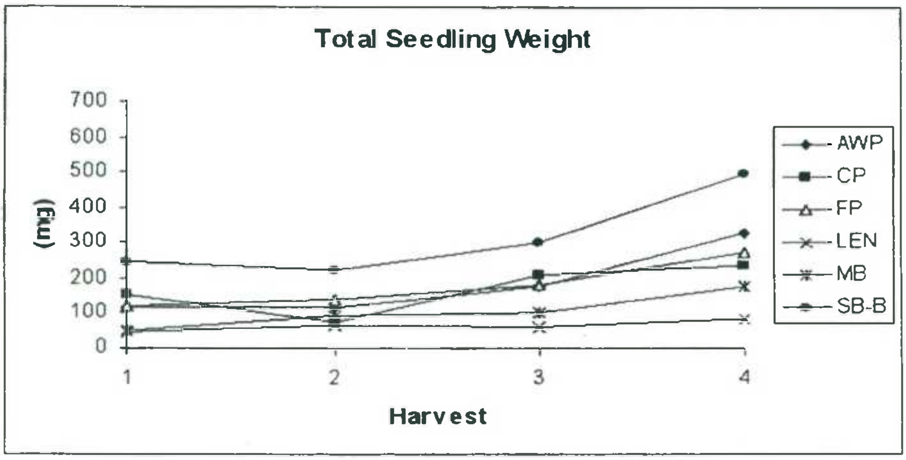

Figure 9. Total Seedling weight with pouches

As in the case with the dark growth experiment, cotyledon weight decreased at each harvest. Soybean once again had the heaviest cotyledon at each harvest with 187 mg (Figure 10). In relation to one hundred seed weight, the cotyledon weights for each legume followed the same trends with soybean having the heaviest cotyledon and lentil having the lightest.

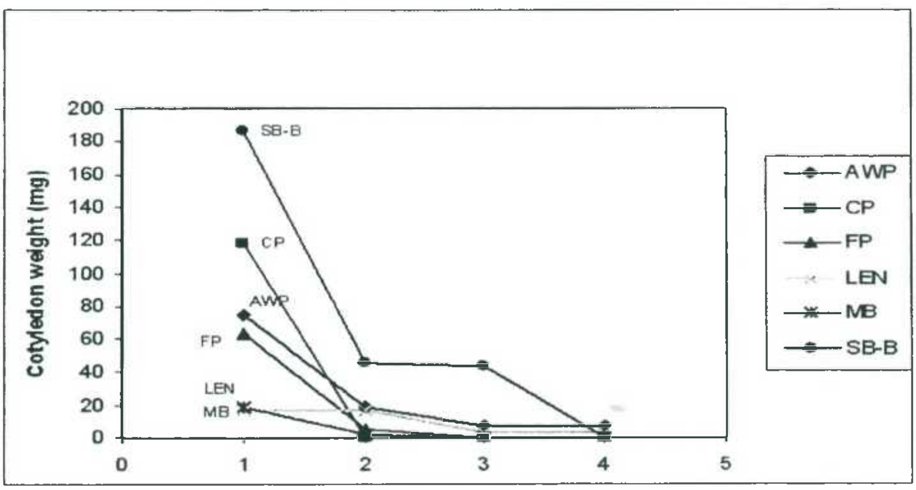

Figure 10. Average cotyledon weight in pouches by harvest.

The shoot dry weight of the legumes increased with each harvest, which is expected because growth is taking place. Soybean had the heaviest shoot at each harvest (Figure 11). At H4, the shoot dry weight of soybean was 340 mg; almost double that of the next shoot dry weight of field pea (188 mg). Also, as in the dark-growth experiment and total dry weight lentil registered the lightest shoot dry weight. Soybean also had the greatest increase of shoot dry weight at any harvest.

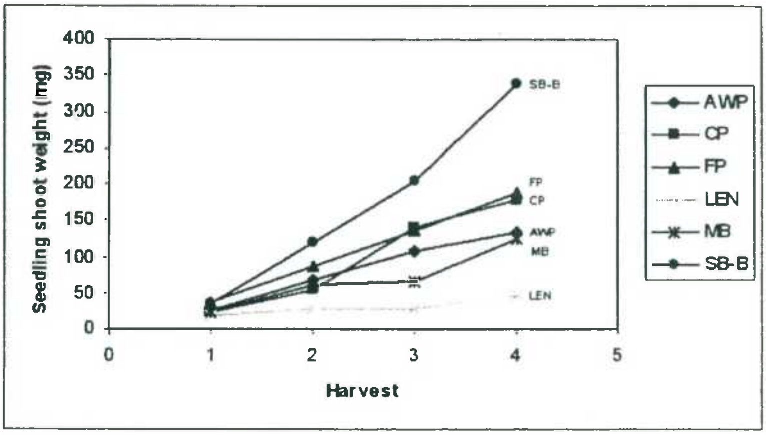

Figure 11. Average shoot weight under light conditions with pouches

Root dry weight of the legumes was different from that of total dry weight and shoot dry weight, in that Austrian winter pea registered the heaviest root mass by H4 (185 mg, Figure 12).

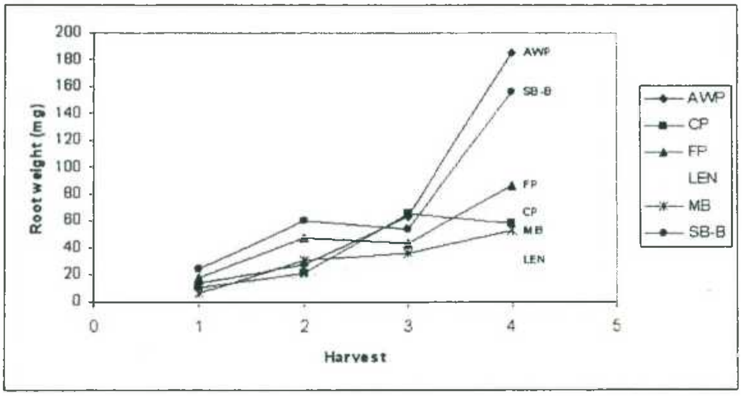

Figure 12. Average root weight under light conditions with pouches

With the exception of H3, where cowpea had the heaviest root dry weight (66 mg), Austrian winter pea had the heaviest root dry weights. For the first two harvests, soybean had the heaviest roots, but for H4 was less than Austrian winter pea. The trend was still the same for lentil registering the lightest root dry weight as was noted in the earlier studies.

Cone-tainers

The cone-tainer study results were similar to those of seedlings grown in pouches under light. Some of those similarities were increases in dry weight and seedling length by harvest and a decrease in cotyledon dry weight by harvest. For example, total seedling dry weight for H1, ranged from 38 mg (lentil) and 171 mg (soybean) (Figure 13). Also similar to the pouch study, soybean had the heaviest seedlings for the first three harvests, but cowpea had the heaviest seedling at H4 with 835 mg and soybean following with 644 mg. Field pea, mung bean, Austrian winter pea and lentil followed with final weights of 477 mg, 380 mg, 338 mg and 109 mg.

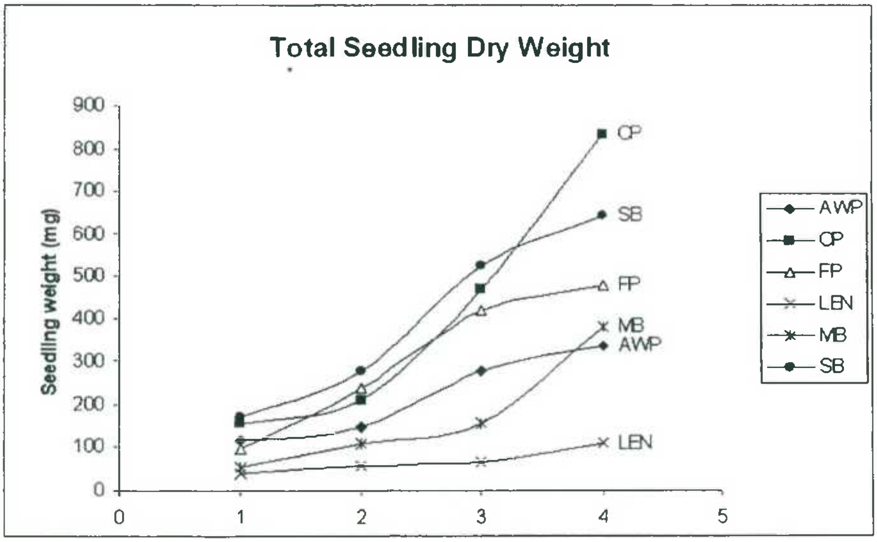

Figure 13. Cone-tainer experiment total average weight of seedlings.

As in previous experiments, cotyledon weight decreased with each harvest. In relation to one-hundred seed weight, soybean had the heaviest cotyledons at each harvest until H4 (Figure 14), at which time some of the cotyledons had detached from the seedlings. By H2, except for soybean and Austrian winter pea, cotyledons of the remaining legumes had detached.

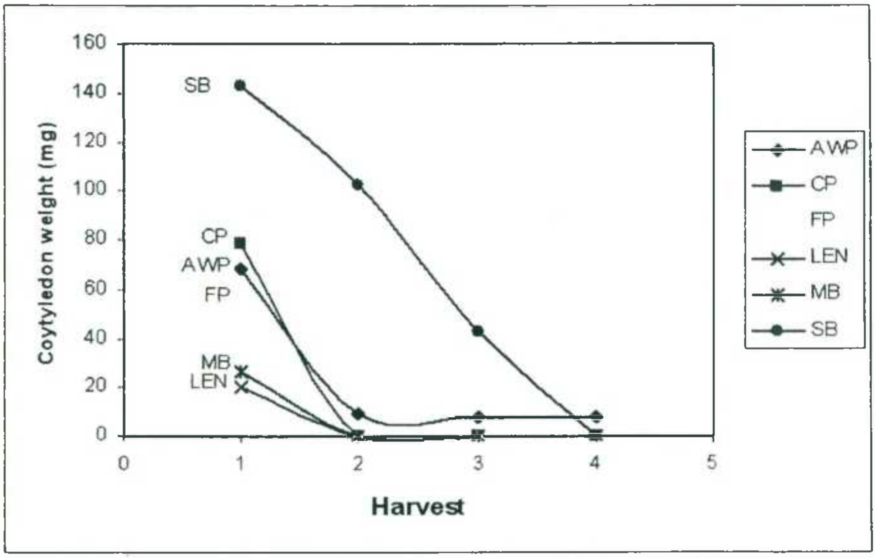

Figure 14. Conte-tainer experiment average cotyledon weight under growth chamber conditions

As in the previous light study, shoot dry weight increased at each harvest. For the first two harvests, shoot dry weights were similar ranging from 14 mg to 64 mg at H1, and from 45 mg to 185 mg at H2 (Figure 15). At H3, separation in the shoot dry weights became more noticeable, and by H4, cowpea had the heaviest shoot dry weight (702 mg). Soybean, field pea, mung bean, Austrian winter pea and lentil followed with shoot dry weights of 516 mg, 408 mg, 326 mg, 273 mg, and 88 mg, respectively. Again lentil displayed the lightest shoot dry weight at each harvest.

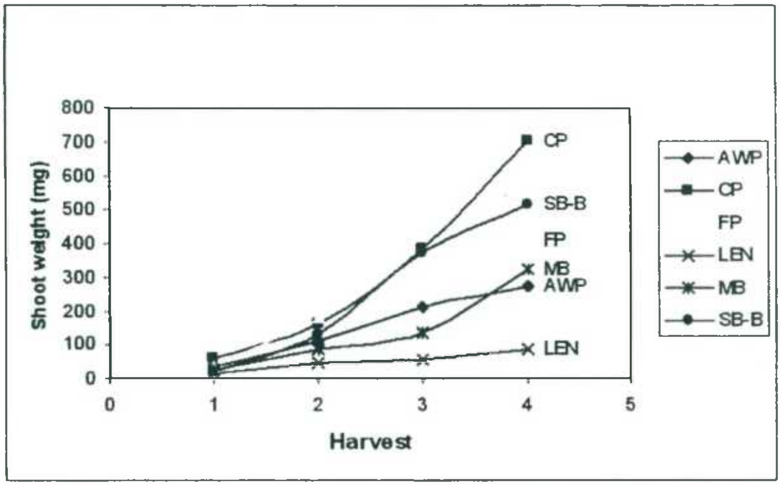

Figure 15. Cone-tainer experiment average shoot dry weight by harvest.

Similar to total seedling dry weight cowpea, soybean and field pea had the heaviest root dry weights of 133 mg, 128 mg, and 69 mg, respectively for the final harvest (Figure 16). Root dry weight separation became apparent at H2 with field pea having the heaviest root dry weight (55 mg) and lentil having the lightest root dry weight (13 mg). As in the previous studies, lentils root dry weigh was the lightest at each harvest, as well as having the least amount of dry weight gain at any harvest.

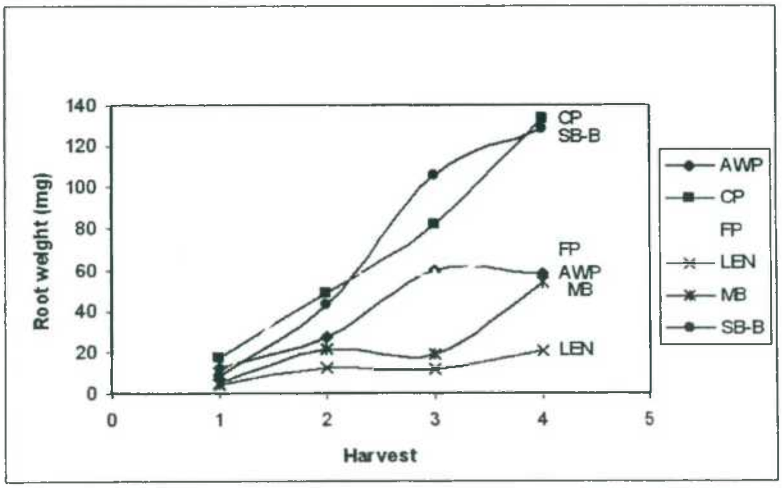

Figure 16. Cone-tainer experiment average root dry weight by harvest.

Unlike dry weight data, shoot lengths of the six legumes were quite different. Austrian winter pea and lentil had the longest shoots at each harvest (Figure 17). At H1, Austrian winter pea and lentil measured 91 mm and 104 mm, conversely while soybean had the shortest shoot (59 mm). As stated earlier, Austrian winter pea was the longest with 563 mm (almost double of the next shoot length) at the final harvest, while lentil, soybean, mung bean, cow pea and field pea followed with 294 mm, 291 mm, 206 mm, 199 mm, and 196 mm, respectively

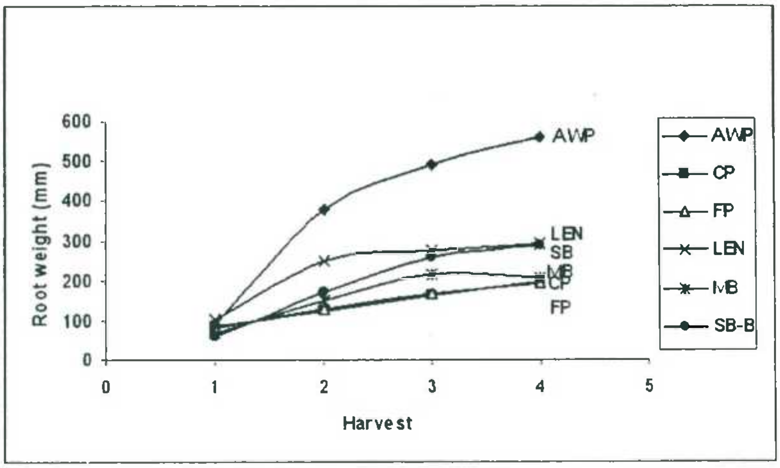

Figure 17. Cone-tainer study average shoot length.

Competition Study:

The grasses decreased the seedling growth of both legumes. The wheat seedlings were more competitive than the ryegrass. By species, the average weights of the legumes were 404 mg for the controls, 343 mg for ryegrass, and 237 mg for wheat. The maximum dry weight for each legume was 535 mg for AWP and 274 mg for SB. When grown with wheat, the weights were reduced to 299 mg for AWP and 175 mg for SB (Figure 16). Pooled legume weight at the first and second harvests was 142 mg and 667 mg, while the legume weight was reduced to 117 mg and 375 mg at the first and second harvests, when grown in competition with wheat. Pooled over treatments and harvests AWP was the more competitive than SB and wheat was the more competitive than ryegrass. At each harvest, the average total weight per treatment more than doubled, with AWP increasing from 148 mg to 921 mg and SB from 136 mg to 412 mg for the controls. When competing with ryegrass, the dry weight for AWP was 152 mg at the H1 and 705 mg at H2. Soybean dry weight was 123 mg at the first harvest and 391 mg at the second harvest when competing with ryegrass (Figure 17). The competition with wheat proved to be different. Dry weights were significantly lower with AWP averaging a total weight of 128 mg at the H1 and 469 mg at the H2. Soybean was out competed by wheat; the dry weight at H1 was 105 mg and for H2 245 mg.

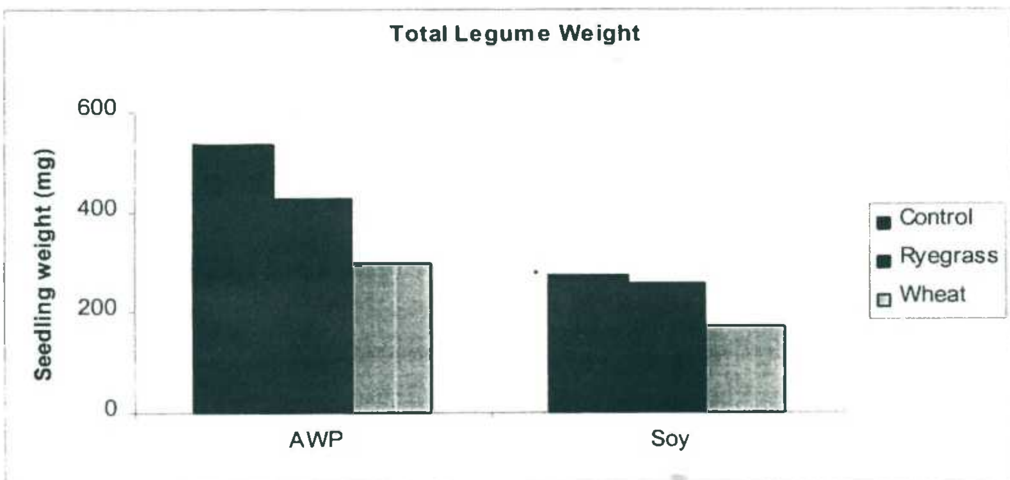

Figure 16. Competition study total average weight presented for both harvest and all treatments. Weed competition had an effect of growth.

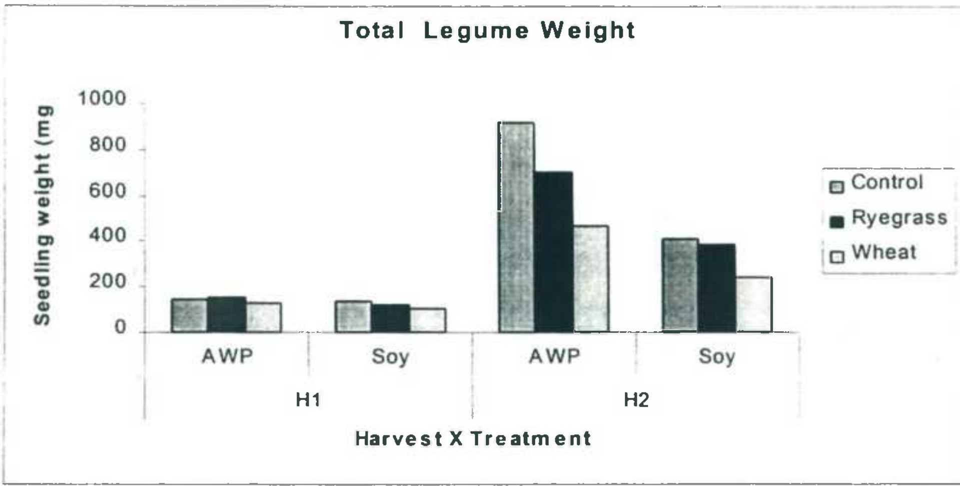

Figure 17. Competition study total average legume weight by harvest vs. treatment. Notice wheat had an effect on seedling weight.

Individual legume part dry weights reflect the total dry weight results presented above. The average dry root weight for AWP showed that wheat at four seedlings per cone-tainer had the greatest effect on root growth with the dry root weight of 50 mg and this result the same for SB with 22 mg. For AWP, the least affected root dry weight (162 mg) occurred in competition with ryegrass at four seedlings per cone-tainer. The control weight was second with 135 mg. There did not appear to be a significant difference in SB root weight except when competing with wheat at four plants per cone-tainer as in the case with AWP. For the first harvest of both legumes, there was little difference in dry root weight, but by the second harvest, the results were similar to those in other results. The heaviest dry root weight for AWP was with four ryegrass plants weighing 295 mg. The control, two ryegrass plants, two and four wheat plants followed with 243 mg, 176 mg, 171, 82 mg. The results were the same for SB four wheat seedlings having the greatest effect on growth, but at the second harvest root weight was fairly uniform (Figure 18).

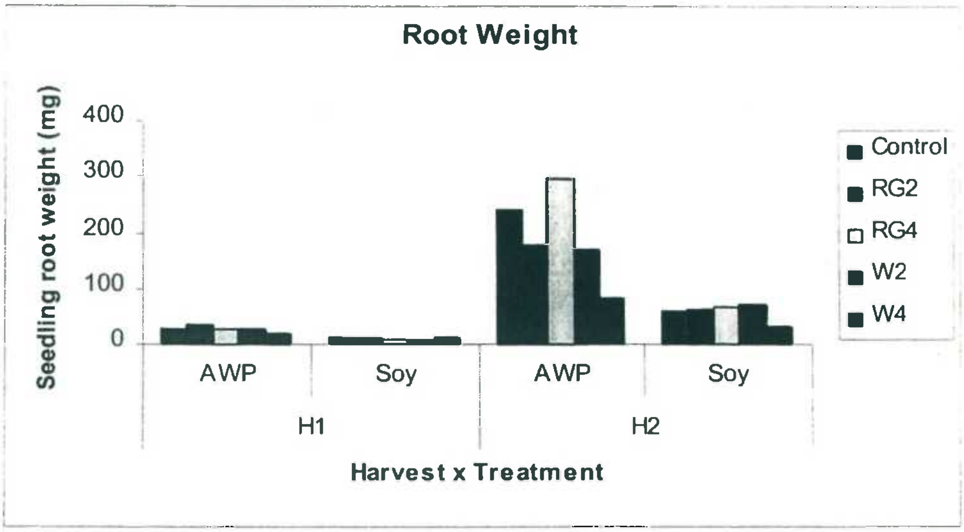

Figure 18. Competition study average legume root weight.

The total average shoot weights pooled together by observation were different from that of the dry root weights. The control had the heaviest shoot weight of 277 mg and the lightest weight was wheat with four (W4) plants at 129 mg. Two and four ryegrass (RG2 and RG4) plants were about the same with 216 mg and 215 mg, respectively. When separating each legume into treatment four wheat seedlings had the greatest effect on dry shoot weight. The dry shoot weight for AWP control was 386 mg and 175 mg for W4. The dry shoot weight for SB control was 167 mg and 83.3 for W4 (Figure 19).

Separately and by harvest there were no differences in shoot dry weight until the second harvest for each legume. Austrian winter pea in both harvests was greatest affected by the W4 treatment weighing 66 mg at harvest 1 and 140.3mg and harvest 2. The lowest dry shoot weight for SB of 23 mg was the W2 treatment for harvest 1 and the W4 treatment for harvest two of 140 mg. For both legumes, the control had the heaviest dry shoot weight at harvest 2 with AWP weighing 670 mg and SB 312 mg (Figure 20).

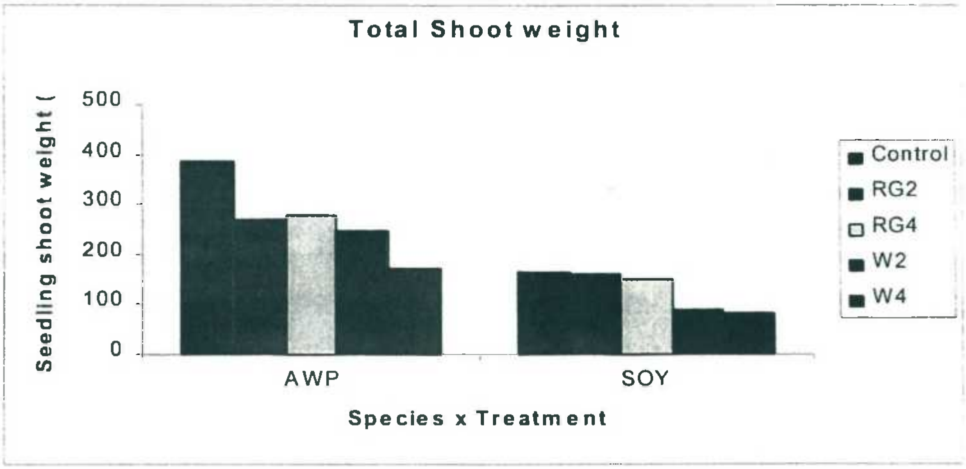

Figure 19. Competition Study average legume shoot weight by treatment.

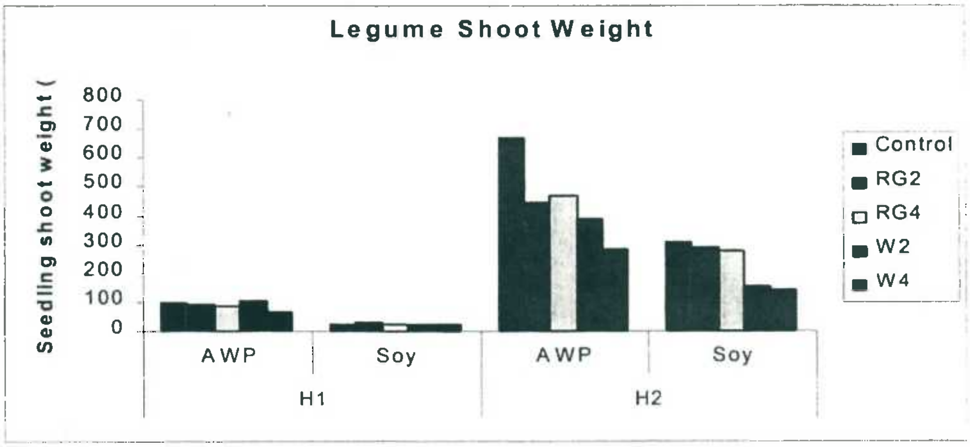

Figure 20. Competition Study average legume shoot weight by harvest.

CONCLUSION

Early establishment of crops is critical in seedling competition. Dark growth experiments can be used to determine which legumes are capable for early seedling establishment By seedling weight and other factors soybean would be the more competitive crop and able to establish itself. Since the other legumes had similar growth characteristic by the final harvest, I would say that they are equally competitive. Even though, soybean proved to be more competitive legume in the pouch study, emergence patterns had no true effect in the light studies. When competition occurred, weed density had a direct effect on growth, and wheat at four seedlings proved had the greatest affect on dry weights as well as growth where ryegrass did not. Although Palta and Peltzer (2001) reported that ryegrass had a large effect on wheat growth, we did not observe this in the present study. Austrian winter pea, a cool season legume, was more competitive than soybean. However, the air temperature may have been too low for optimal soybean seedling growth, a warm season legume. Although Austrian winter pea was more competitive, emergence type did not seem to have an effect in this study. Future research to test emergence effect could be to introduce pests during early germination and growth trials in extreme temperatures for short periods. Other possibilities may be to select a legume that has both hypogeal and epigeal emergence such as pigeon pea varieties, and then select seed seeds of larger size and weight. Being that emergence did not play a big role in competition, size and weight may play a key role in early establishment as reported by Smart and Moser (1999).

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