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Step Wise Regression and Path Analyses of Dry Matter Accumulation in the Vegetative and Reproduction Parts of Soybeans (*Glycine max* [L] Merr)

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Abstract: Studies on accumulation rate, association and stepwise regression of agronomic character to pod and seed yield were carried out among cultivars of soybeans. Field experiment was laid out in a randomized complete block design with a split plot arrangement and replicated 3 times. The cultivars were allocated to the main plot, while the stages of maturity were allocated to the sub plot. Representation samples were analyzed for accumulation of photostynthate in the shoots roots and seeds as affected by the stages of maturity. The result indicated a significant difference for pod length, plant height, dry shoot weight dry pod wall weight and dry weight as affected by the stage of maturity. The accumulation of photosynthate in the seed was highest (3.15±1.69) in Tgx 923-2E. A positive correlation between seed weight and number of branches, pod number per plant and pod wall weight, suggests that these characters may be components for improvement in seed yield. The stepwise multiple regression analysis identified the pods per plant to have accounted for 96% of variability for seed weight. The seed weight contributed 96% of the total variation observed for pod yield. The number of pods per plant recorded the highest positive direct effects on weight. This study identified the number of pods per plant as important character for pod yield improvement in soybeans.

Key words: Path analysis, photosynthate, source and sink, stepwise regression

INTRODUCTION

Soybeans (*Glycine max* [L] merr) vegetable parts (including the roots) are the only sink for assimilate prior to the flowering. During flowering and fruit set, vegetable and reproductive plant parts are competetory sink for assimilate. However, the fruits (pods) are the primary sink for assimilate during seed filling (Zeiber *et al*., 1982). The proportion of assimilate allocated to the reproductive parts during the flowering and fruit set could be important in determining fruit and seed number. Sink activity in developing seeds consist of sequential activities for assimilate cells. However, physiological characters are responsible for difference in yielding capacity of pulses (Pathik *et al*., 1993). It is apparent that the photosynthate utilized daily for seed development in soybeans is mostly derived from canopy photosynthesis (Egli and Leggetti, 1976). The pod in soybeans is the primary sink for photosynthate during seed development and consequently accumulation of dry weight in the pod (pod wall and seed) is an important process in yield production in soybeans (Egli and Leggetti, 1976). However, Egli *et al*. (1978) indicated that during seed growth in soybeans, a positive association of genetic difference in seed size and seed growth rate was observed. It has been shown that the length and width of soybean pods are maximum before seed growth begins (Andrews, 1996). However the pod wall may continue to increase in dry weight during seed development (Stretters and Jeffer, 1979).

Seed yield in soybeans is the product of a complex hierarchy of physiological process affected by genes (Mahan, 1983) and are closely related to the number of pods and seeds that develop on the plant (Shibles *et al*., 1978). Fruit set and the number of seeds that develop may be related to the availability of assimilate to the reproductive organs (pod and seeds) during flowering and fruit set (Herlholt *et al*., 1985), which will affect assimilate partitioning during the period. In addition, grain weight in soybeans is the product of grain filling duration and grain filling rate to Herlholt *et al*. (1985). The grain filling duration is the stage between flowering and physiological maturity. In seed crop improvement the knowledge of the relationship among quantitative characters with seed yield is essential as an aid to the choice of appropriate parameter to be used in selection. Correlation analysis may be insufficient to explain relationship among character necessary for improvement in pod and seed yield. Therefore, the knowledge of inter character association is important for indirect selection of character that exhibit a low heritability (pod and seed yield). Soybeans are widely cultivated across growing ecologies in Nigeria, but the Savannah agro-ecological zone is the most favorable for soybean production. In Akwa-Ibom State, soybeans cultivation is carried out in a small scale, because of the problem of seed germination resulting from soil acidity, poor physical properties of the soil, climate requirements and lack of information about seed development and the accumulation of dry matter in the vegetative and reproduction parts. This study is important as its findings will provide information, which will assist breeders to develop the most suitable cultivars for most areas. The objectives of the study are: To study the accumulation of dry matter in the shoot and seeds of soybeans at different stage of maturity, to determine association among characters and component characters for pod and seed yield in soybeans.

MATERIALS AND METHODS

A field experiment was conducted at the Teaching and Research farm, University of Uyo, in a high rainfall area of the South Eastern Nigeria. The site is located between latitude 0.50°N and longitude 07.50°NE, on a gently sloppy and fairly flat terrain. The mean annual rainfall was 188.10 cm with a mean monthly relative humidity of 722.5%, a mean maximum air temperature of 30.72°C and a minimum air temperature of 22.48°C and mean sunshine hours of 3.31 h day^{-1}. The experimental site was cleared, ploughed and harrowed. The four cultivars of soybeans (Tgm 579, Tgx-536-02D, Tgx 713-09D and Tgx-923-2E) were obtained from the germ plasm collection of the international institute of Tropical Agriculture, Ibadan. The soil analysis indicated a pH of 5.98, organic matter of 1.56%, nitrogen of 0.08%, available P {meq kg^{-1}} of 133. Exchangeable basis {meq 100 g^{-1}}: Ca of 3.8 mg, Na of 0.31;K of 0.87, exchangeable acidity {meq 100 g^{-1}} of 5.26, effective cation exchange capacity {ECEC} {meq 100 g^{-1}} of 12.17% and base saturation of 36.65. A randomized complete block design with split plot arrangement, replicated three times was adopted for the study. Each plot had a length of 15 m and a width of 10 m. The four cultivars of soybeans were allocated to the main plot factor of the experiment. The stages of maturity (75, 80, 90, 95, 100, 105 DAP) was allocated to the sub plot factor. Two seeds of each cultivar were planted at a spacing of 60 cm by 5 cm. Cultural practices as weeding and thinning were carried out.

Twenty soybeans seedlings were harvested randomly from each plot of the experiment at 75, 80, 90, 95, 100 and 105 days after planting for the estimation of dry root weight and dry shoot weight. From each plant sample harvested at each stage of maturity, 30 pods with a minimum of three seeds per pod were randomly harvested for analysis of pod length, pod width, pod wall weight and dry seed weight. Pod length was measured as a straight line from the peduncle to the tip of the pod and the width was measured on the widest point from suture to suture across the pod in centimeter. Seeds and pod wall from thirty pods were oven dried at 70°C for determination of seed and pod wall dry weight, while plant height was measured with a meter rule from the ground level to the top of the main stem. The number of pods per plant was estimated by randomly tagging twenty soybeans plants per plot and counting the number of pods per plant at each stage of maturity. Data collected for accumulation of dry matter at different stages of maturity, were subjected to analysis of variance of a split plot design (Snedecor, 1956). Correlation among physiological characters was carried out using SPSS version 7.5 software on windows. Using seed weight (g) from 30 pods and pods per plant as dependent variable, regression analysis was carried out as outlined by Steel and Torrie (1960). Important characters associated with seed weight and pod yield were determined by using the multiple stepwise regression analysis. The direct and indirect causes of seed yield were analyzed as described by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Combined analysis of variance for dry matter accumulation rate for nine characters of soybeans as affected by the stages of maturity (Table 1) showed significant differences ($p<0.05$) among stages of maturity (75, 80, 85, 90, 95, 100 and 105 DAP) for plant height, dry root weight, dry shoot weight, pod wall weight, pod length and width. This indicated that the accumulation of dry weight in the shoots, pod (pod wall) in the cultivars differs at each stage of maturity. A significant difference for pod length, dry root weight, pod wall weight, dry shoot weight and plant height among the cultivars (factor A) suggest a differential response among the cultivars studied in the accumulation of photostynthate in the pods (pod wall), roots and shoots. A statistical significant ($p<0.05$) interaction effects for dry root weight, pod width, pod length, number of branches, dry shoot weight and plant height indicated a greater dependence of the accumulation of photosynthate in these plant parts (cultivars) at each stage of maturity.

An increase in the accumulation of photosynthate in the seeds and pod wall from 75-100 DAP Table 2 and 3, suggest an increase in dry matter accumulation per unit of fresh seed volume as the seeds mature. The accumulation of photostynthate in the seeds was maximum (3.15±1.69) in Tgx 923-2E. However, the occurrence of a maximum dry matter accumulation in the seeds at 100 DAP might denote the attainment of

Table 1: Combined analysis of variance for physiological characters as affected by the stages of maturity in Glycine max

	Df	DSW	Pht	Dshw	Nobr	Pdl	Pdw	Pd/plt	Drw	Pdwt
Factor A(Varieties)	3	7.19ns	136.74*	20454.94*	130.86*	2.34*	0.07*	6223.57*	7497.39*	5.43*
Error a	6	3.55	9.08	200.25	5.05	0.52	0.07	1064.80	1122.05	0.39
Factor B(Maturity days)	6	25.7ns	2293.48*	10216.72*	2.18ns	0.56*	0.14*	13479.30ns	2271.18*	11.58*
AB	18	18.55ns	24.05*	889.10*	9.07*	0.74*	0.02*	282.49ns	362.83*	2.18*
Error b	36	27.71	9.63	16.25	1.65	0.03	0.002	15177.83	47.83	0.10

* = Significant at 1% probability level, NS= Not Significant: Dsw = Dry seed weight, Pht = Plant height, Dshw = shoot dry weight, Nobr = Number of branches, Pdl = Pod length, Pdw = Pod width, Pd/plt = Pods per plant, Pdw = Pod wall weight, Drw = Dry root weight

Table 2: Mean dry matter accumulation rate in Soybeans (Glycine max)

Dsw	Phf	Dshw	Pd/plt	Pdwall	Nobr	Pdl	Pdw	Drw
A 2.62±1.50	48.40±11.79	86.37±24.38	95.96±31.80	5.80±0.61	9.86±2.53	4.20±0.10	0.62±0.10	59.46±16.68
B 1.80±1.54	50.95±12.75	70.71±24.71	60.66±22.14	6.37±1.64	7.19±1.08	4.10±0.27	0.55±0.09	53.85±23.28
C 2.04±1.14	52.88±11.62	130.14±34.43	68.00±29.16	6.62±0.87	12.86±1.59	4.29±0.22	0.63±0.14	96.21±15.20
D 3.15±1.69	51.99±12.39	117.32±33.02	105.00±37.03	6.91±0.86	12.76±1.17	3.32±0.55	0.52±0.08	69.5.±11.13

A = Tgx-536-02D, B =Tgm 579, C = Tgx-713-09D, Tgx-923-02E, Dsw = Dry seed weight, Phf = Plant height at flowering, Dshw = Dry shoot weight, Pd/plt = Number of pods per plant, Pdwt = Pod wall weight, Nobr = Number of branches per plant, Pdl = Pod length, Pdw = Pod width, Drw = Dry root weight

Table 3: Mean±variance of dry matter accumulation as affected by the stages of maturity in Glycine max

	75DAP	80DAP	85DAP	90DAP	95SDAP	100DAP	105DAP
Dsw	0.36±0.17	1.23±0.57	2.61±0.41	2.71±0.88	3.39±0.87	4.25±0.76	3.67±0.49
Phf	34.36±0.91	40.50±2.39	45.84±2.67	51.23±4.10	56.17±5.87	60.64±6.63	73.80±2.02
Dshw	112.42±12.82	127.58±31.06	129.0146.63	113.65±42.60	83.39±13.19	93.47±25.06	65.85±23.87
Pd/plt	28.75±3.96	47.50±10.59	68.4312.33	78.50±18.61	106.75±25.09	111.68±16.75	114.50±20.67
Pdwt	4.97±0.63	5.32±0.42	6.68±0.62	6.80±1.90	6.78±0.58	7.25±0.83	7.20±0.99
Nobr	73.23±22.19	83.66±10.83	95.02±18.24	61.18±13.38	55.62±21.61	60.02±25.07	53.56±22.80
Pdl	9.67±1.80	9.49±2.001.80	9.19±3.34	10.42±2.64	11.25±2.75	1.34±2.42	10.83±1.95
Pdw	3.79±0.14	4.36±0.07	3.71±0.46	4.02±0.58	4.02±0.58	4.00±0.53	3.97±1.18
Drw	0.36±0.01	0.58±0.04	0.63±0.07	0.68±0.08	0.65±0.08	0.61±0.06	0.58±0.07

Dsw= Dry seed weight, Phf = Plant height at flowering, Dshw = Dry shoot weight, Pd/plt= Number of pods per plant, Pdwt= Pod wall weight, Nobr= Number of branches per plant, Pdl= Pod length, Pdw= Pod width, Drw= Dry root weight

physiological maturity in the varieties evaluated in this environment. An increase in the accumulation of photostynthate in the seeds, pod wall, shoots across the maturity dates (75-105 DAP) suggest a concurrent accumulation of photosynthate. This however, indicates that the pod wall and seeds might have competed for assimilate during seed growth, thus reducing the number of seeds that develop per pod. In furtherance, the pod walls are suspected as temporary storage for seed bound assimilate, because of its proximity to the seeds. Tgx 923-2E recorded the maximum dry matter accumulation in the pod wall (6.91g±0.86) among other varieties evaluated. Hence, it could serve as component for production of livestock feed. The fluctuation in the accumulation and loss of photosynthate by the roots and shoots may be attributed to a competition between the source and the sink. In addition, the pod length showed increases from 75 DAP and 80 DAP, but pod width increased from 0.36cm±0.01 to 0.68cm±0.04, between 75 and 90 DAP. However, the pod length was maximum (4.29cm±0.22) at 80 DAP among other cultivars evaluated. Apparently, the study indicated that the pod length was maximum in most cultivars evaluated before a substantial accumulation of photosynthate in the seeds began. The fluctuation in the pod length may be attributed to the accumulation and loss of photosynthate by the pods.

The study showed that the number of pods per plant increased from 75-105 DAP. But the number of pods was highest (114.50) at 105 DAP. This may be attributed to the vigour of the plant to produce flowers and assimilated for seed growth and development. Tgx-923-2E recorded the highest (105) number of pod weight (Table 2), followed by Tgx 536-02D (95.96g) suggest that the varieties could perform better in this environment if selected for genetic evaluation in pod and seed yield.

A positive correlation (Table 4) between dry seed weight from 30 pods and dry shoot weight (r = 0.34) pods plant (r = 0,98**) pod wall weight (r = 0.22), number of branches (r = 0.55) suggest these characters as components of seed yield in this environment. Physiological improvement aimed at increasing the accumulation of photosynthate in the seeds will substantially necessitate same in these characters. Therefore any of these characters could serve as a good index for improvement in the physiological process for increase seed yield. A significant and a positive association between seed weight from 30 pods and pod per plant (r = 0.98*) indicated that as more photosynthate are produced for production of pod, the seed dry weight increase simultaneously. However, a positive association between seed weight and the number of branches per plant (r = 0.55) ordinarily suggest a complementary action

Table 4: Correlation analysis among component characters in Soybeans (Glycine max)

Phf	Dshw	Pd/plt	Pdwt	Nobr	Drw	Pwt	Dsw
Dshw	0.70*	-0.31	0.90*	0.54*	-0.21	-0.22	-0.14
Pd/Plt		0.23	0.63*	0.97*	-0.24	0.18	0.34
Pdwt			0.29	0.46	-0.67*	-0.26	0.98*
Nobr				0.56*	-0.64*-0.36*	-0.56	0.22
Drw						0.13	0.55
Pdw						0.84*	-0.78*
Dsw							-0.37
							-0.71*

Dsw = Dry seed weight, Phf = Plant height at flowering, Dshw = Dry shoot weight, Pd/plt = Number of pods per plant, Pdwt = Pod wall weight, Nobr = Number of branches per plant, Pdl = Pod length, Pdw = Pod width, Drw = Dry root weight

Table 5: Stepwise multiple regression analysis indicating contribution of some agronomic characters Soybeans (Glycine max)

Characters	No in	Seed weight R^2	Cumulative
Pods/plant	1	0.96	0.96
		Pods $plant^{-1}$	
Seed weight	1	0.96	0.96
Pod length	2	0.98	0.02

Table 6: Calculation of direct and indirect effect on dry seed weight in soybeans

	Pd/plt	Nobr	Dshw
Pd/plt	0.65	0.32	0.008
Nobr	0.41	0.33	0.06
Dshw	0.07	0.06	0.21

Residual Effects) = 0.86, Pd/plt= Number of pods/ plant, Nobr = Number of branches/plant, Dshw = Dry shoot weight

of these characters in accumulation of photosynthate in the seeds. This may be related to a greater photosynthetic capacity provided by more leaves, since the branches bear most of the leaves, which manufacture photosynthate for pod and seed growth. Seed weight recorded a significant negative correlation with pod length (r = 0.78*) and dry root weight (r = 0.71*), this trend explain the independence of these characters in the production of assimilate for seed growth. A competition in assimilate distribution among these characters is expected. Apparently a negative correlation between the number of pods per plant and pod length (r = 0.67), pod width (r = -0.26) and pod dry weight (r = -0.15) could suggest a competition for assimilate in the production of pods. However, a negative correlation between plant height and pods per plant (r = -0.31) indicated that shorter plants will produce a higher number of pods and vice versa. A significant and positive correlation between pod length and width (r = 0.84*), suggest a complementation in the distribution of assimilate, this trend agrees with Bravo *et al.* (1980) in Lee variety of soybeans A negative correlation coefficient (r = -0.31) in the association between pods per plant and plant height suggest the effectiveness of shorter cultivars in channeling photosynthate for higher pod yield for vegetative growth (plant height).

The results from the stepwise multiple regression analysis (Table 5) identified two characters, seed weight and pod yield to have explained 90% of variability observed in pods per plant. The remaining characters did not meet the (r = 0.05) significance level of entry into the model. However these two characters positively correlated with pods per plant. This same analysis demonstrated that the number of pods per plant accounted for 96% of observed variation in seed weight.

Table 6 shows the direct and indirect contributions of three characters that positively correlated with seed yield in soybeans. The number of pods per plant has the highest positive direct effect (0.65) in seed yield. It also recorded a significant correlation coefficient with seed yield. Other characters (number of branches per plant, dry shoot weight) recorded a positive direct effect and a significant positive correlation indirect that selections may be evinced from association studies. In addition, this further confirms the large contribution of pod per plant for a high seed yield. Improvements in seed yield can be achieved through election for pods per plant in soybeans. The residual factors were positive and it accounted for 80% of observed variation. The number of pods per plant recorded a positive direct effect (065) in seed weight and a positive indirect effect via the number of branches (0.32) to complement seed yield. Considering the significant positive association between seed weight and number of pods per plant and a large positive direct effect of the number of pods in seed weight. The number of pods per plant appeared to be the most reliable index for improvement in seed weight in soybeans.

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