SEED AND SEEDLING SIZE RELATIONSHIP IN CASTOR (*RICINUS COMMUNIS* L.)

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ABSTRACT

The seed weight in Castor (*Ricinus communis* L.) averaged to 309.99 ± 0.16.016 mg and varied 15.4-folds i.e. around 51.4%. The seed weight distribution was asymmetrical (negatively skewed) and platykurtic. Out of 101 seeds sawn (seed weight: 33.7 - 515.8 mg), twenty seven seeds of seed weight varying from 33.7 to 245.5mg could not germinate. Within the range from 248.6 to 515.8 mg, the seed weight appears not to influence the final seedling emergence percentage. The critical seed weight to affect emergence, therefore, appeared to be around 248 mg. Larger seeds gave rise to larger seedlings. The cotyledons developing from larger seeds were larger in size. The hypocotyl length related with seed size in curvilinear fashion but varied greatly and their lengths could be accounted for only around 10% by the seed weights. The seed size, on the other hand, influenced stem dry weight quite effectively. The dry weight of the seedlings (roots + stem + cotyledons + leaves) increased significantly (r = 0.6582, p < 0.00001) with the increase in seed weight. Pigments such as Chlorophyll-a, chlorophyll-b, total chlorophylls and carotenoids concentrations were not significantly affected by the seed size within the range of 248.6 to 484.2 mg.

Key Words: Castor (*Ricinus communis* L), Seed Weight Variation, Germination / Emergence, Seedling Growth.

INTRODUCTION

The variation in seed size is known to affect the population dynamics of a species. It may influence several plant processes e.g., germination and emergence of seedlings (Shaukat *et al*., 1999)), Seedling establishment (Sachall, 1980), growth of seedlings and survivorship (Marshall, 1986; Aziz and Shaukat, 2010) and competitive ability of adult plants (Stanton, 1984). Larger seeds generally tend to be advantageous producing seedlings more likely to survive and grow more rapidly than those arising from smaller seeds (Shaukat *et al.,* 1999). Since, seed weight variation may be of greater significance in variable or patchy environment (Janzen, 1977); the ecological significance of seed weight in a species can not be over-emphasized. The individual seed weight in a species is reported to vary from nearly constant (Harper *et al*., 1970) to as high as 16-fold (Mazer, 1987) due to several factors such as genotype variation, competition for the limited resources, environmental history to which mother plants are exposed, and trade off between seed mass and number of seeds per fruit.

Ricinus communis L. (Castor) is agriculturally important species, seeds of which yield useful oil. In this paper we have investigated regma weight, size and packaging coast of seeds and the effects of seed size variation on germination and seedling growth of this species.

MATERIALS AND METHODS

Seed Mass variation

A sample of 101 hundred seeds from a lot of Castor seeds collected from University of Karachi campus in 2011 were randomly chosen and weighed individually on electronic balance. The frequency distribution of seed mass was constructed and location and dispersion statistics were calculated and symmetry, skewness and kurtosis were tested. Normal distribution was checked by drawing Q-Q plot for seed mass data and also by K-S d, the Kolmogorov-Smirnov test (Zar, 1994).

Seedling Emergence and Growth

In order to evaluate the effect of seed weight on germination / seedling emergence and growth, 101 seeds varying in size from 33.7 to 515.80 mg (CV: 51.92%) were sawn at the rate of one seed per pot admeasuring 6 cm in diameter and containing 120g sandy loam soil collected from experimental field of Botany department, University of Karachi and fertilized homogenously with garden manure. The pots were maintained at 75% field capacity under temperature $26 \pm 2^{o}C$ in growth room. The sowing depth in each case was kept constant at 1.0 cm. The emergence was recorded daily for a week. The seeds which couldn't emerge were excavated to check their germination. The crop of synchronously emerged seedlings was allowed to grow for 15days when the seedlings were harvested carefully – not to damage roots. The length and fresh and dry weights of roots, shoots, and seedlings were recorded. The number of leaves per seedling was counted and the area of each cotyledon and leaf was determined to estimate the total photosynthetic area of each seedling. Area of the cotyledons (ovate in shape) was recorded as Cotyledonary area = Length x breadth x 0.786. The coefficient 0f 0.786 was determined arithmetically by evaluating area of the cotyledon by graphic method. The area of leaf (palmate) was estimated as leaf area = L x W x 0.55, where L was the maximum length and W the maximum width of the leaf as suggested by Jain and Misra (1966) for castor leaf.

The data was analyzed statistically with SPSS v. 10 for determining the influence of seed size with the observed seedling characteristics. Gini's coefficient (Gi), a measure of inequality or size hierarchies was calculated with seed mass data and the growth parameters of seedlings arising from these seeds. Gini's coefficient is equal to one-half of the relative mean difference i.e. arithmetic average of the differences between all pairs of individuals. Its value varies from 0 to 1(Weiner and Solbrig, 1984).

$$Gi = \sum_{i=1}^{n} \sum_{j=1}^{n} | x_i - x_j | / (2n^2 \bar{x})$$

The calculated values were multiplied by n / (n-1) to give unbiased estimates (Wiener, 1985). This index has been used successfully in many studies pertaining to the measurement of inequality (Waller, 1985; Khan and Shaukat, 2000).

Estimation of chlorophylls and carotenoids: Contents of chlorophyll-a, chlorophyll-b and total chlorophylls were determined by the method of Strain *et al.* (1971) using following regression equations.

Chlorophyll - a $(\mu g.g^{-1})$ = 11.63 (A_{665}) − 2.39 (A_{649})
Chlorophyll - b $(\mu g.g^{-1})$ = 20.11 (A_{649}) − 5.18 (A_{665})
Total Chlorophyll $(\mu g.g^{-1})$ = 6.45 (A_{665}) + 17.72 (A_{649})

The carotenoids were determined with the method of Duxbury and Yentsch (1956) using the following regression equation.
Carotenoids $(\mu g.g^{-1})$ = 7.60 (A_{480}) − 2.63 (A_{510})

RESULTS AND OBSERVATION

Seed Weight Variation

The seed weight of castor employed in the experiment varied from 33.70 to 515.8 mg (mean = 309.99 ± 16.016 mg (Fig.1). The coefficient of variation was 51.92%. The seed weight distribution appeared to be asymmetric (negatively skewed) and platykurtic. The Kolmogorov-Smirnov d was 1.875 significant at p > 0.002. This statistics indicated that distribution of seed weight was not normal as also indicated by the Q-Q plot (Fig.2).

N = 101
Mean = 309.99 mg
SE= 16.016
Q_1 = 197.55
Q_2= Median = 368.0
Q_3 = 425.15
CV = 51.92%
Minimum = 33.70
Maximum = 515.80
g_1 = -0.793
Sg_1 = 0.240
g_2 = -0.903
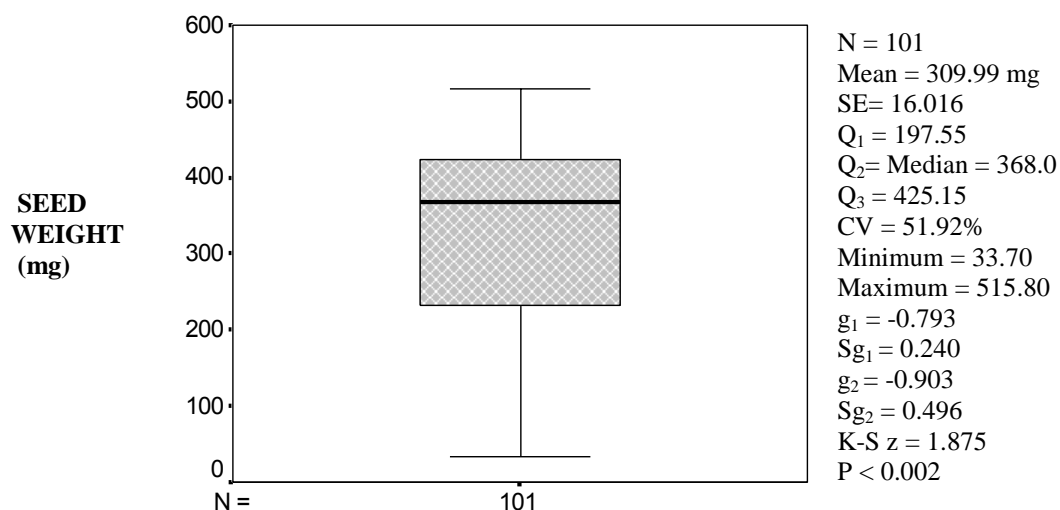Sg_2 = 0.496
K-S z = 1.875
P < 0.002

Fig. 1. Box plot representation of seed weights of 101 seeds employed in the experiment.
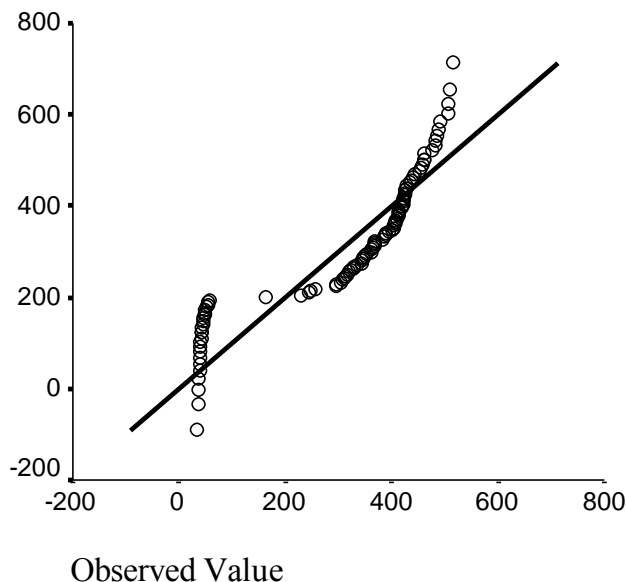
Fig. 2 Q-Q plot of the seed weight (N = 101) as a test to the normal distribution.
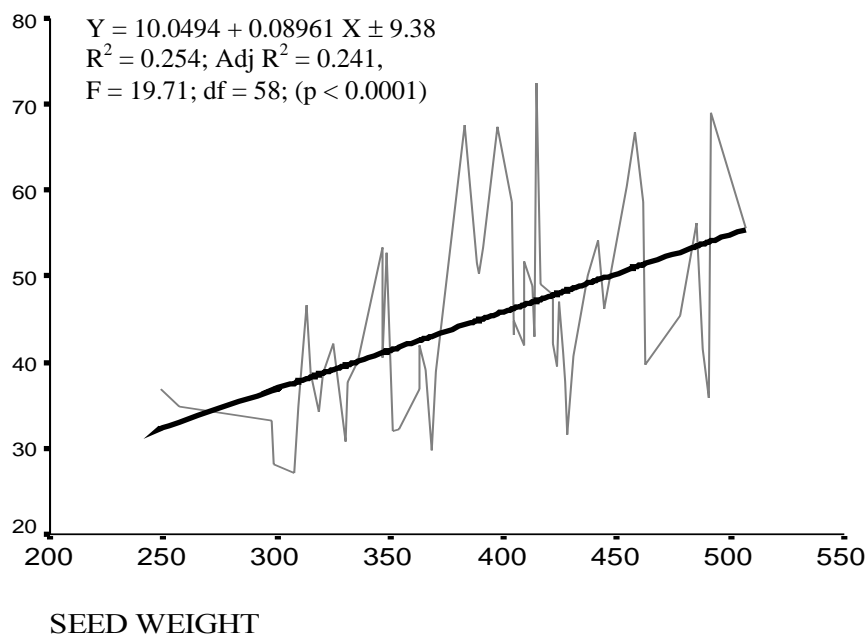
$$Y = 10.0494 + 0.08961 \ X \pm 9.38$$
$$R^2 = 0.254; \ Adj \ R^2 = 0.241,$$
$$F = 19.71; \ df = 58; \ (p < 0.0001)$$

Fig. 3. Relationship of cotyledonary area (cm^2) with seed weight (mg).

Emergence and Seedling Growth

The seeds varying from 33.7 to 515.80 mg in weight were employed to investigate the effect of seed weight on germination, emergence and the seedling growth. The emergence was completed within five days. Twenty seven seeds of seed weight from 33.7 to 245.5mg could not emerge at all. After 10 days, the seeds which failed to emerge were excavated and it was found that seeds up till seed weight of 245.5 mg were either non-filled or ill-filled. Two seeds weighing 415.6 and 420.8 mg indeed germinated but couldn't emerge due to some unknown reasons. Two seedlings arising from seeds of 422.3 and 434.2 mg died after eight days of emergence. Within the range from 248.6 to 515.8 mg, the seed weight appears not to influence the final emergence percentage. The critical seed weight to

affect germination / emergence may, therefore be expected to be around 248 mg. However, there were 60 seedlings which emerged almost synchronously and they were allowed to grow for 15 days and were included in the growth analysis. Data on several growth parameters was collected and statistically analyzed through correlation and regression between seed weight (independent variable) and observed growth parameters (dependent variables).
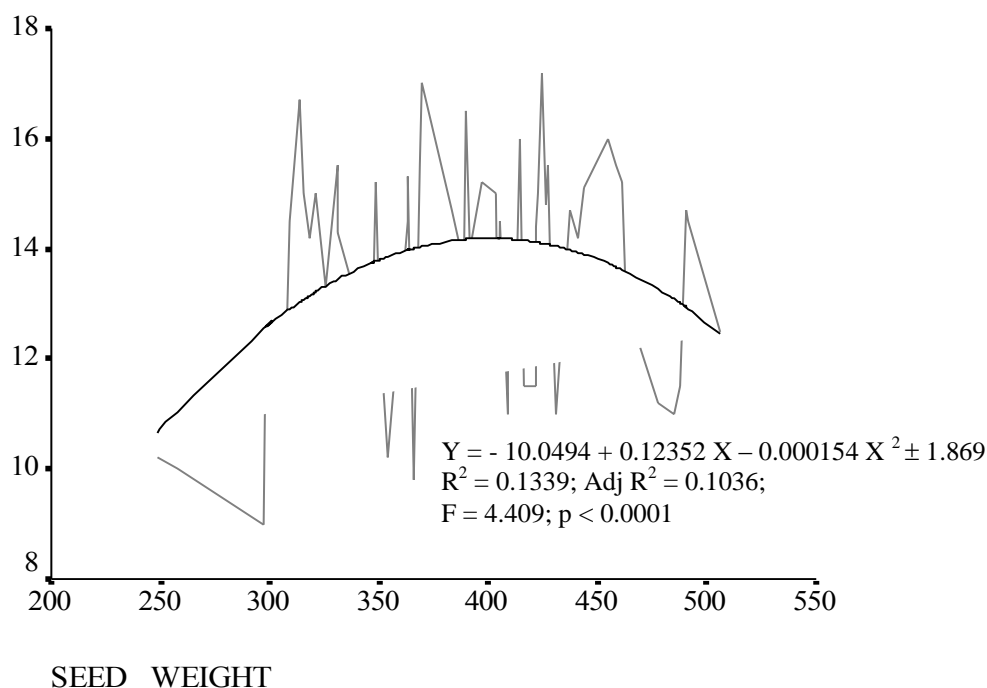

$$Y = -10.0494 + 0.12352\,X - 0.000154\,X^2 \pm 1.869$$
$$R^2 = 0.1339; \text{Adj } R^2 = 0.1036;$$
$$F = 4.409; p < 0.0001$$

SEED   WEIGHT

Fig. 4. Relationship of hypocotyl length (cm) with seed weight (mg).

$$Y = 47.00499 + 0.19814X \pm 46.301$$
$$R^2 = 0.0638; \text{Adj } R^2 = 0.0477$$
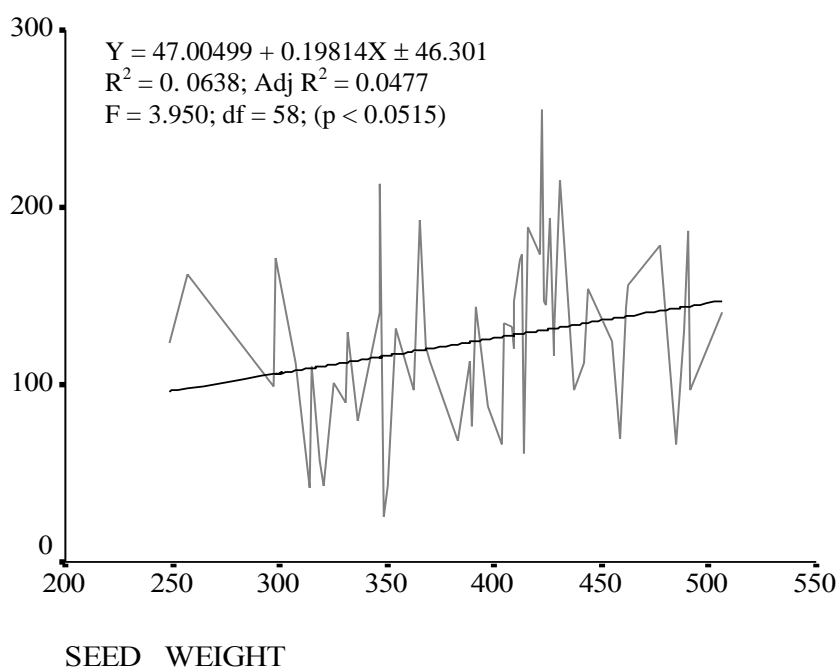$$F = 3.950; df = 58; (p < 0.0515)$$

SEED   WEIGHT

Fig. 5. Relationship of root dry weight (mg) with seed weight (mg).

The cotyledonary area per seedling varied significantly among the seedlings arising from the seeds whose weight ranged from 250 to 505.5 mg. The cotyledons developing from larger seeds were larger in size. There was significant correlation between the two parameters ($r = 0.4949$) The seed size appeared to account for around 25% of the variation in cotyledonary size ($F = 19.7$, $p < 0.00001$) (Fig. 3). The hypocotyl length related with seed size in curvilinear fashion. The variation in hypocotyl length data was, however, large and seed size could account for only around 10 % of the variation in hypocotyl length (Fig. 4). Similarly, root dry mass although correlated positively but
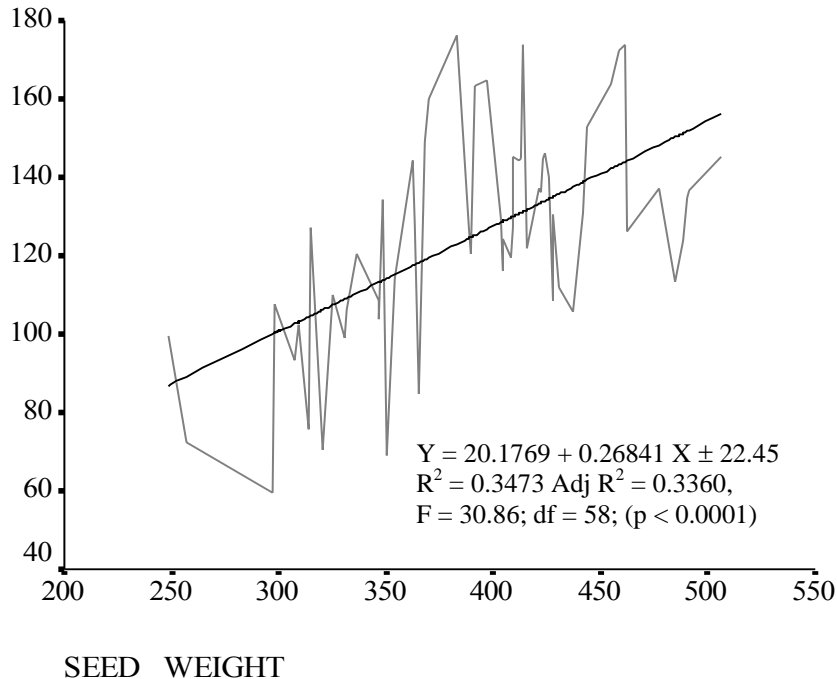
$$Y = 20.1769 + 0.26841\ X \pm 22.45$$
$$R^2 = 0.3473\ \text{Adj}\ R^2 = 0.3360,$$
$$F = 30.86;\ df = 58;\ (p < 0.0001)$$

SEED   WEIGHT

Fig. 6. Relationship of stem dry weight (mg) with seed weight (mg).

$$Y = -22.4661 + 0.0.94172\ X \pm 77.24$$
$$R^2 = 0.3561;\ \text{Adj}\ R^2 = 0.3450,$$
$$F = 32.08;\ df = 58;\ (p < 0.0001)$$
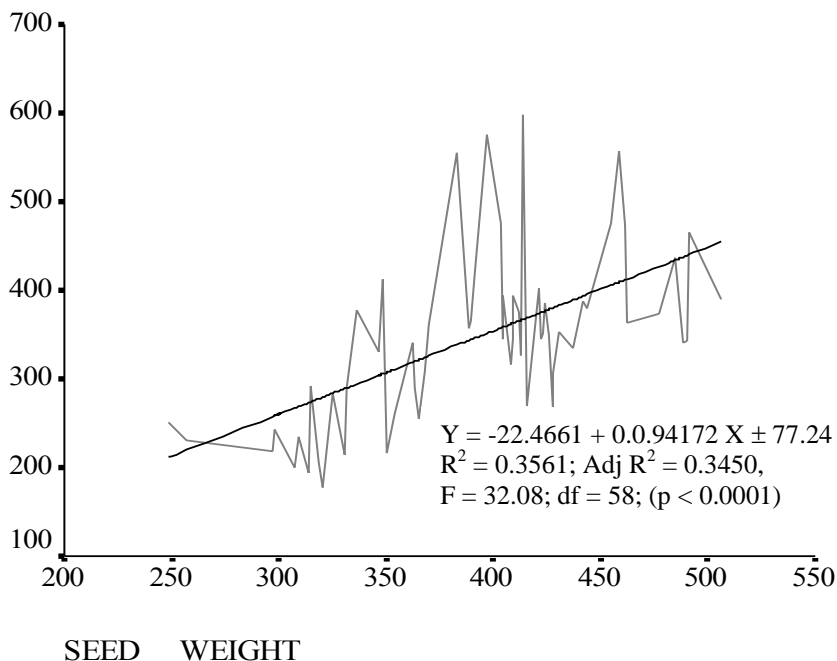
SEED   WEIGHT

Fig. 7. Relationship of shoot dry weight (mg) with seed weight (mg).

marginally ($p < 0.0515$) with seed size and seed size could account for only around 5% of the variation in root weight (Fig. 5). The seed size, on the other hand, influenced stem dry weight quite effectively. There was direct correlation between the two parameters ($r = 5893$) and stem growth was influenced by the seed size around 33.6% (Fig. 6) The shoot growth behaved similarly (Fig. 7).

$$Y = 30.89063 + 1.12219 \pm 78.30$$
$$R^2 = 0.4332; \text{Adj } R^2 = 4264,$$
$$F = 44.33; df = 58; (p < 0.0001)$$
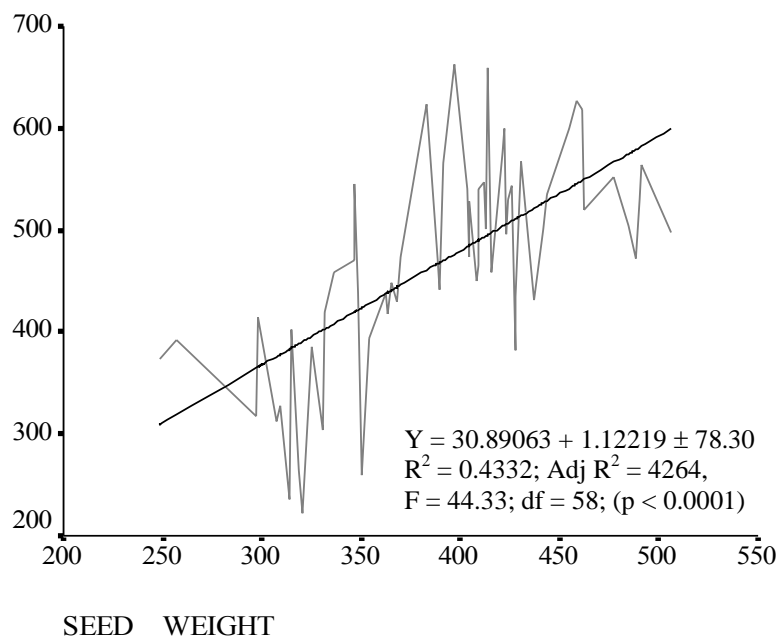
SEED   WEIGHT

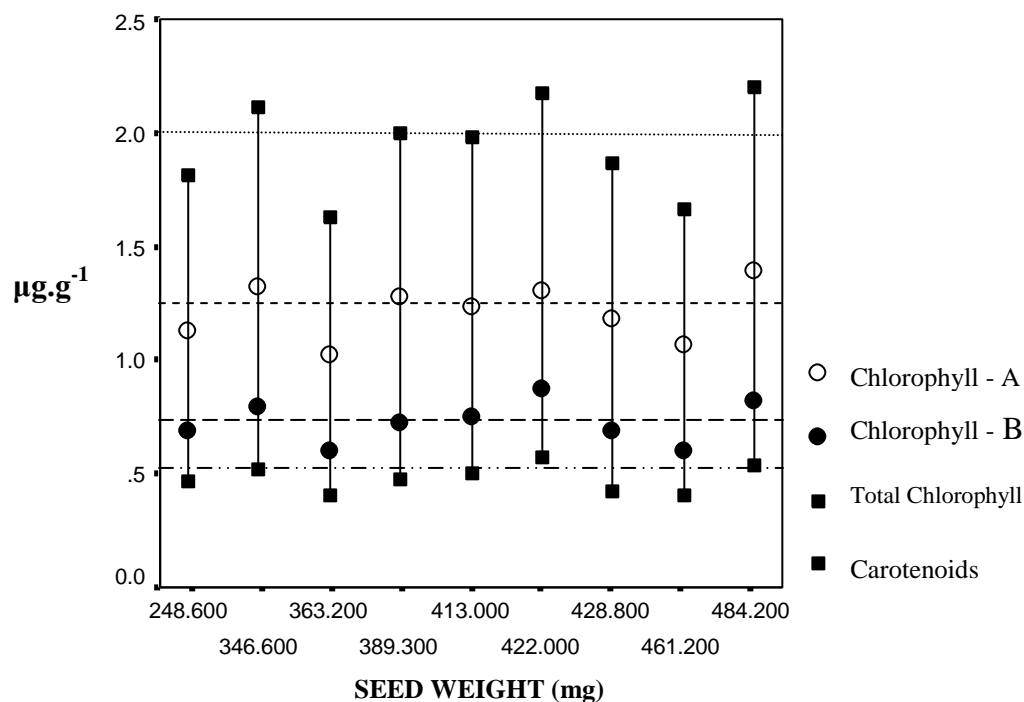Figure 8. Relationship of plant dry weight (mg) with seed weight (mg).

Fig. 9. Pigments concentration in fresh leaves of seedlings of *Ricinus communis* arising from seeds of different weights varying from 248 to 484 mg. Horizontal lines represents the mean value of the pigment.

It is obvious from Fig. 8 that the dry weight of the seedlings (roots + stem + cotyledons + leaves) increased significantly (r = 0.6582, p < 0.00001) with the increase in seed weight and around 43% of the plant growth variation was explained by the seed size variation.

Chlorophylls and carotenoids

No clear cut pattern or trend was apparent in chl. - a, chl. - b, total chlorophylls and the carotenoids contents in the leaves of seedlings arising from seeds ranging in weight from 248.6 to 484.2 mg (Fig. 9).

Seed Weight and Seedling Growth Inequalities

Data on location, dispersion and size inequality (Gi, Gini index) of seeds and seedling growth parameters for seedlings arising from the seeds employed in the growth analysis are presented in Table 1. The inequality or size hierarchy among seeds employed in the experiment in term of seed weight was 0.08732. The maximum inequality among the seedlings arising from these seeds was given by the leaf area (0.39675) followed by the inequality as evident from the epicotyl length (0.33783). The seedling hierarchy was generally higher for each growth parameters of seedlings except hypocotyl length. It is then obvious that the seed weight hierarchy was more translated in the seedling growth hierarchy of these seedlings which have grown with no competition among themselves, being grown singly in separate pots.

Table 1. Mean seed size and size inequality of seeds and seedling.

Parameter	Mean	SD	CV (%)	Gi
Seed weight (mg)	390.47	60.48	15.49	0.08732
Cotyledonary Area (cm^2)	44.83	10.68	23.82	0.14245
Leaf Area (cm^2)	29.58	24.66	83.38	0.39675
Photosynthetic area (cm^2)	74.615	33.804	45.305	0.22666
Shoot Length (cm)	15.31	2.53	16.52	0.09280
Root Length (cm)	23.10	7.494	32.44	0.18397
Hypocotyl Length (cm)	13.620	1.972	13.16	0.08119
Epicotyl Length (cm)	1.685	1.1014	65.36	0.33783
Shoot dry weight (mg)	344.75	95.29	27.65	0.15057
Root dry weight (mg)	124.38	47.45	38.15	0.21298
Plant dry weight (mg)	468.57	103.1	22.00	0.12226
Average seedling hierarchy			36.9	0.1975

N= 60.

DISCUSSION

The weight of individual seeds of castor employed in the experiment varied 15.4-folds i.e. from 33.70 to 515.8 mg (mean = 309.99 ± 16.016 mg; CV = 51.92%). The seed weight distribution appeared to be negatively skewed and platykurtic. The Kolmogorov-Smirnov d was 1.875 significant at p > 0.002 which indicated that distribution of seed weight was not normal as also indicated by the Q-Q plot. Wide intraspecific variations of seed mass have been reported in several tropical species (Janzen, 1977; Foster and Johnson, 1985; Khan *et al.,* 1984; Khan *et al.* 1999, 2002; Khan and Umashanjkar, 2001; Murali, 1997; Marshall, 1986; Upadhaya *et al.,* 2007). Seed weight variations of the order of 19 to 23% have been reported in species like *Ipomoea sindica*, *Cleome viscosa*, and *Digera muricata* (Aziz and Shaukat, 2010). Seed weight variation in *Thespesia populnea* is around 27% (Zahida, Personal Communication). Khan *et al.* (1984) have reported seed weight variation in desert herbs to be around 6.82 % in *Achyranthes aspera*, 12.91% in *Peristrophe bicalyculata*, 14 % in *Cassia holosericea* and 16.83% in *Prosopis juliflora,* a tree legume. *Opuntia ficus-indica* exhibited seed weight variation c. 18.2% (Khan, 2006). Michaels *et al.* (1988) have examined 39 species (46 populations) of plants in eastern-central Illinois and reported variability (in terms of coefficient of variation) of seed mass commonly exceeding 20% - significant variation being among the

conspecific plants in most species sampled. Busso and Perryman (2005) have reported seed weight variation in sage brush to lie between 26.31 and 31.75% amongst the sites and years of study. Sachaal (1980) found 5.6 fold variation among 659 seeds collected from a population of *Lupinus texensis*. The variation in seed weight in Castor was, thus, quite high; being around 15.4 folds and comparable to that reported by Mazer (1987) to be 16-folds.

Seed size may be the result of myriad of factors (Fenner and Johnson, 1986; Wulff, 1986). Earlier impression of seed weight constancy in earlier ecological literature seems to be arising primarily from observations of the relative constancy of mean seed mass in some plant species rather than an analysis of the variability among individual seed masses which have demonstrated considerable variability. Winn (1991) has suggested that plants may not have the capability of producing a completely uniform seed weight simply as a result of variations in resource availability (e. g., soil moisture during seed development). Seed size is significantly reduced under moisture stress in mature trees of walnut (Martin *et al.,* 1980). Seed weight is said to be direct function of precipitation (moisture availability) and monthly precipitation is reported to explain around 85% of the total variation in seed weight in Wyoming sage brush (Busso and Perryman, 2005). Seed weight is also reported to decline with age in walnut (*Juglans major*) in terrace habitat of central Arizona (Stromberg and Patten (1990). Seed weight has also been reported to be the function of plant height in a population of *Ranunculus acris* (Totland and Birks, 1996). The large variation among plants suggests a potential for but not necessarily the presence of genetic control of seed size. This is because maternal parents may influence seed size via both maternal genetics and the maternal environment effect (Roach and Wulff, 1987; Busso and Perryman, 2005).

Seed weight distribution in Castor was found to be negatively skewed and platykurtic. Seed mass was found to be normally distributed in *Blutapason portulacoides* and *Panicum recemosum* but not in the case of *Spartina ciliata* (Cardazzo, 2002). Seed weight distribution is known to vary even within a species and to be dependent on site quality and year of study – varying from symmetry to skewness, from leptokurtic to platykurtic (Busso and Perryman, 2005). It may be due to trade-off in resource allocation between seed size and number (Venable, 1992) or environmental heterogeneity (Janzen, 1977). Even intra-cultivar variation in seed mass has been reported (Fasoula and Boerma, 2007; Khan *et al.,* 2011; Anis *et al.,* 2011).

The emergence of seedlings in Castor was completed within five days. Twenty seven seeds of weight from 33.7 to 245.5mg could not emerge at all being either non-filled or ill-filled. Of course, two seeds weighing 415.6 and 420.8 mg although but couldn't germinate due to some unknown reasons, within the range from 248.6 to 515.8 mg, the seed weight appeared not to influence the final emergence percentage. The critical seed weight to affect germination / emergence may, therefore, be expected to be around 248 mg. Seeds above this critical weight germinated very well. No relationship of seed size and germination is also reported by Bentley *et al.,* 1980). Espahbodi *et al.,* (2007) has reported no significant correlation between seed size and germination percentage in *Sorbus tormanalis*. Close and Wilson (2002) also found no correlation in seed weight and germination rate in *Eucalyptus delgatensis*. In some plants, larger seeds are not reported to give higher germination rate e.g., in *Glycine max*, the higher rate of germination was found to be related to smaller seeds (Tiwari *et al.,* 1982). Larger seeds of Castor, however, produced larger seedlings. Such an effect of larger seeds on growth of emerging seedlings has been reported in many species of plants e.g., *Blutapason portulacoides, Panicum recemosum* and *Spartina ciliata* (Cardazzo, 2002), *Acacia nilotica* (Shaukat *et al.,* 1999), *Senna occidentalis* (Saeed and Shaukat, 2000), and in some desert herbaceous species such as *Cleome viscosa, Digera muricata, Ipomoea sindica* (Aziz and Shaukat*, 2010).* Larger seeds are better adapted to withstand cotyledon damage in *Teflaria occidentalis* (Iortsuun *et al.* (2008). Higher seed mass promotes seedling vigour in *Prunus jenkinsii* (Upadhaya *et al.,* 2007) and produces larger roots (Roach, 1986). Such seedlings may emerge from greater soil depth (Bond *et al.,* 1999). Intraspecific variation in seed mass and its relation to seedling survival has been demonstrated in several species (Meyer *et al.,* 1995; Andersson and Milberg, 1998; Aziz and Shaukat, 2010). The pigment concentration in leaves of seedlings, arising from seeds ranging in seed weight from 248.6 484.2 mg, remained unaffected by the seed weight in the present studies. The significantly larger size of seedling arising from the larger seeds should, obviously, be of ecological significance. Such an advantage of growth should obviously give a good start to the larger seedlings than smaller ones but how far this advantage may carried in time is a matter of further research.

The inequality or size hierarchy as given by the Gini index for seeds employed in the experiment, in term of seed weight, was 0.08732. The maximum inequality among the seedlings arising from these seeds was given by the leaf area (0.39675) followed by the inequality in epicotyl length (0.33793) and photosynthetic area (0.2267). Inequality in terms of coefficient of variability (CV %) of the seed weight and the seedling growth behaved in the same manner as Gi. The seedling's average growth inequality on composite basis for all growth parameters was higher than that of seed size inequality whether viewed as Gi or CV (%). It is indicated that the seed weight hierarchy was translated nearly double in the seedling hierarchy in these seedlings which grew with no competition

among them as they have been growing singly in separate pots. It is in agreement with Westoby *et al.* (2002) who opined that the seed mass variation may be reflected in seedling weight variation.

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