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VARIATION IN POD-, BROOD- AND SEED-SIZES AND SEED PACKAGING COST IN *VACHELLIA NILOTICA* SSP. *INDICA* (BENTH.) KYAL. & BOATWR. FROM NAURAJA, KACCHE JO ILAIQO, SINDH, PAKISTAN

D. Khan, Zulfiqar Ali Sahito and M. Javed Zaki

Department of Botany, University of Karachi, Karachi – 75270, Pakistan.

ABSTRACT

Pod and seed characteristics of *Vachellia nilotica* ssp. *indica* (Benth.) Kyal. & Boatwr., a full grown tree growing in Nauraja, Kacche Jo Ilaiqo (floodplain of River Indus, Sindh), were studied which included pod-, seed- and brood-size and seed packaging cost and their variations. In a sample of 130 pods, the pod weight varied from 1.304 to 5.667g averaging to 3.789 ± 0.0685g and followed a normal distribution. The brood size averaged to 11.208 ± 0.1694 seeds per pod varying from 5 to 15 per pod (CV: 17.24%). The amount of seeds recovered from the pods varied from 0.5948g per pod to 2.3864g per pod (CV: 19.5%). The mean individual seed weight in a sample of 1411seeds averaged to 143.51 ± 0.751mg and varied from 3.40 to 205.30 mg (CV: 19.65%). The distribution was found to be non-normal and substantially negatively skewed and leptokurtic. The seed packaging cost on the basis of per seed (SPC1) averaged to 0.1986 ± 0.0058g per seed whereas seed packaging cost on the basis of per g seeds (SPC2) averaged to 1.4464 ± 0.0898g per g seeds. Both SPC1 and SPC2 deviated significantly from the normal distribution.

The results were discussed in context of the available ecological literature.

Key-words: Pod, Brood, seed size, seed packaging, *Vachellia nilotica.*

INTRODUCTION

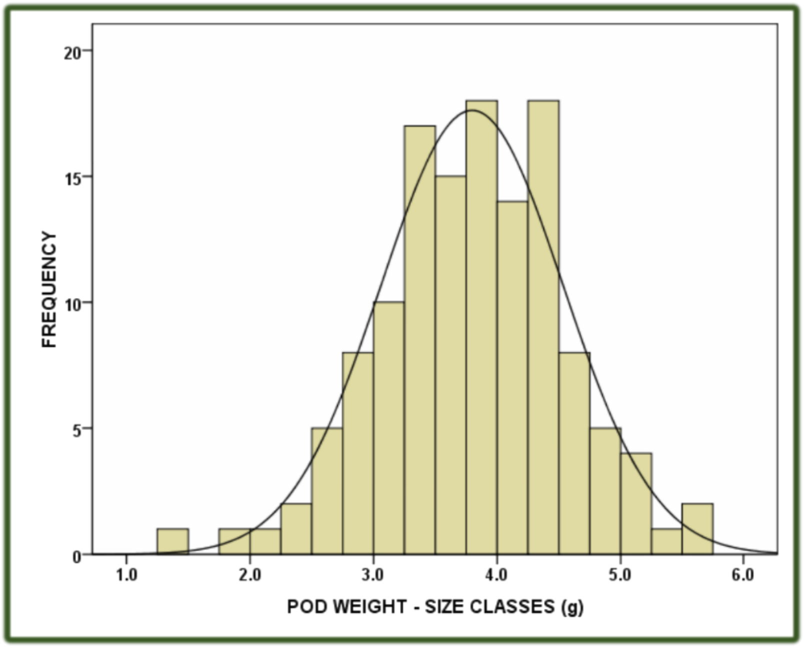
Some studies have quantified reproductive allocation at fruit and seed levels (Obeso, 2004; Lord and Westoby, 2006; Martinez *et al.,* 2007). Fruit size has been frequently suggested to be related to within-fruit biomass allocation between seeds and pericarp (e.g., Herrera, 1987; Willson *et al.,* 1990; Lee *et al.*, 1991; Mehlman, 1993; Celis-Diez *et al.,* 2004; Martinez *et al*., 2007). Within-fruit allocation pattern of biomass, brood size (*sensu* Uma Shaanker, 1988), seed size and seed packaging cost vary from species to species, individuals within species and even amongst fruits of an individual plant due to various reasons (Janzen, 1977; Stanton, 1984; Mendez, 1997; Ganashaiah *et al.*, 1986; Ganashaiah and Uma Shaanker, 1988; Uma Shaanker *et al.*, 1988; Willson *et al.*, 1990; Busso and Perryman, 2005; Chan *et al.,* 2010; Khan and Zaki, 2012; Khan and Sahito, 2013a and b; Afsar Uddin and Khan, 2015; 2016). Within-fruit reproductive allocation parameters in our local flora have been reported under local environment only in few publications e.g. *Cassia fistula* (Khan and Zaki (2012), *Delonix regia* (Khan and Sahito, 2013); *Acacia nilotica (*Afsar Uddin and Khan, 2015), *Albizia lebback* (Afsar Uddin and Khan, 2016). The objective of the present work was to study pod and seed characteristics of *Vachellia nilotica* ssp. *indica*, a full grown tree growing in Nauraja, Kacche Jo Ilaiqo (floodplain of River Indus, Sindh, with reference to the pod and seed sizes and their variation. Also, investigations on brood size and the seed packaging cost are also undertaken. Such studies are ecologically very important as life-history traits in the context of seed size, seed dispersal and seed dormancy (Venable and Brown, 1988) and help us understand plant life-history strategies (Chen *et al.*, 2010).

MATERIALS AND METHODS

One hundred and thirty pods of *Vachellia nilotica* ssp. *indica* were collected from its tree growing in Nauraja, Kacche Jo Ilaiqo (floodplain of River Indus), Sindh, Pakistan in 2012. Pods were kept in laboratory to dry for 100 days. Then each pod was weighed on electric balance. The brood size *(sensu* Uma Shaanker, 1988) i.e. number of seeds per pod was recorded. The seeds were weighed individually on an electrical balance with an accuracy of 0.1mg. After recovery of seeds, residual pod mass (Pericarp) was also weighed.

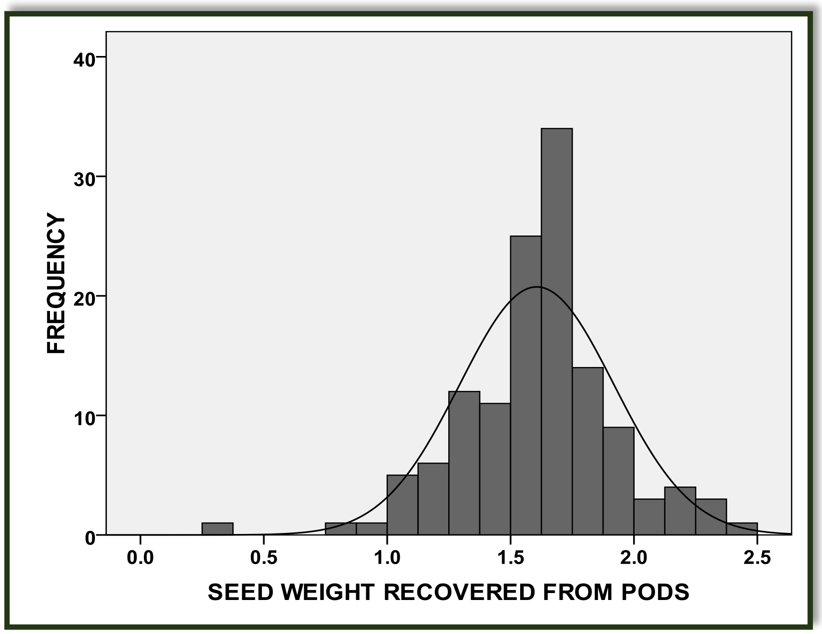
To determine within-pod biomass allocation, the ratio of the mass of the pericarp to the seeds was calculated. The two parameters of seed packaging cost, SPC1 (pericarp mass.g.seed^{-1}) and SPC2 (pericarp mass.g per g seeds), were considered to represent the seeds packaging cost (Mehlman, 1993; Chen *et al.,* 2010, Khan and Zaki, 2012; Khan and Sahito, 2013 a and b; Khan *et al.*, 2013, 2016) in the pods studied.

The location and dispersion parameters of data, wherever necessary were calculated and the frequency distributions were characterized with skewness (g1) and kurtosis (g2). Kolmogorov-Smirnov z test (KS-z test) was performed to detect normal distribution, if necessary (Sokal and Rholf, 1995). KS-z test assesses whether the observations could reasonably have come from the normal distribution. The data was analyzed on canned statistical package - SPSS version 17.



N = 130
Mean = 3.7893g
SE = 0.06483
Median = 3.818
Mode = 4.277
CV = 19.50%
G1 = -0.260
Sg1= 0.212
G2 = 0.525
Sg2 = 0.422
Minimum = 1.3041
Maximum = 5.5665
KS-z = 0.599
P < 0.866

Fig.1. Frequency distribution of pod weight (g) of *Vachellia nilotica* ssp. *indica.*



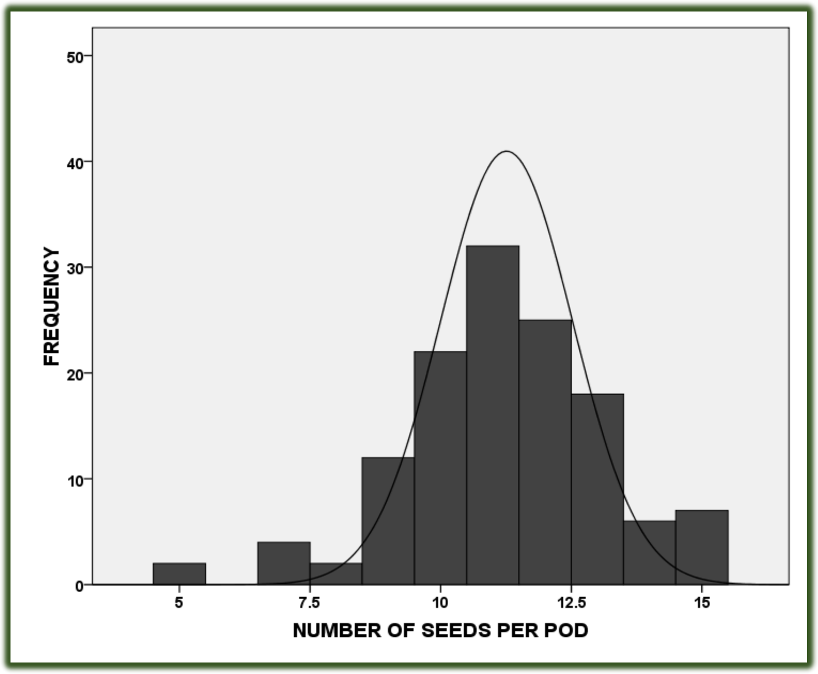
N = 130
Mean = 1.6089
SE= 0.02753
Median = 1.6295
CV (%) = 19.51
G1 = -0.359
Sg1 = 0.212
G2 = 2.177
Sg2 = 0.422
Minimum= 0.5948
Maximum = 2.3864
KS-z = 0.945
P < 0.334

Fig. 2.Seed weight (g) recovered from each of 130 pods. The distribution appeared to be somewhat skewed negatively. Insignificance of KS-z, however, indicated towards the normal distribution pattern. The amount of seeds recovered from 63% of the pods varied from 1.26 to 1.75g.

RESULTS AND DISCUSSION

Pod weight

In a sample of 130 pods, the pod weight varied from 1.304 to 5.667g averaging to 3.789 ± 0.0685g and followed a normal distribution as Kolmogorov-Smirnoff z was insignificant (KS-z: 0.599, p < 0.866) but with variation in terms of CV: 19.51%. The pod mass generally concentrated around the mean value (Fig. 1). Some 63.08% of the pods weighed between 3 to 4.25g. The pod weight of in hand species appeared to be comparable to that reported for *Vachellia* (Acacia) *nilotica* from Karachi (Afsar Uddin and Khan, 2015).



N = 130
Mean = 11.2077
SE= 0.16943
Median = 11.00
Mode = 11.00
CV (%) = 17.24
G1 = -0.417
Sg1 = 0.212
G2 = 0.880
Sg2 = 0.422
Minimum= 5.0
Maximum = 15.0
KS-z = 1.529
P < 0.019

Fig. 3.frequency distribution of brood size (number of seeds per pod).

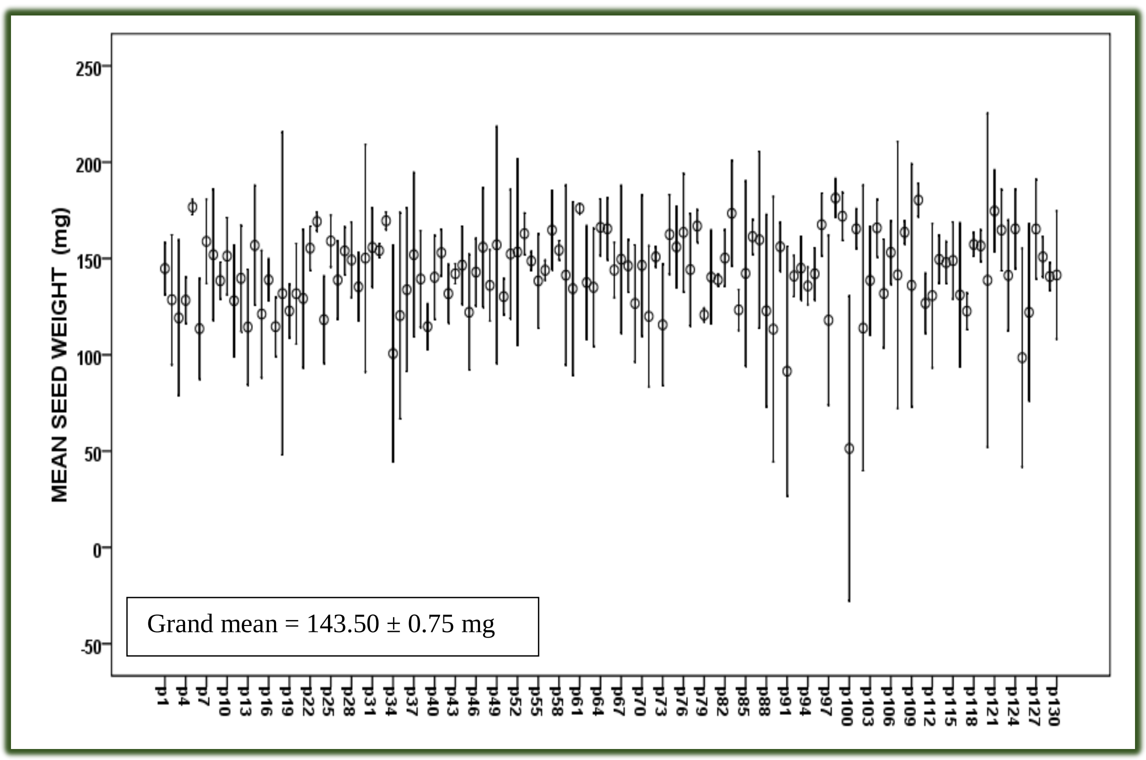
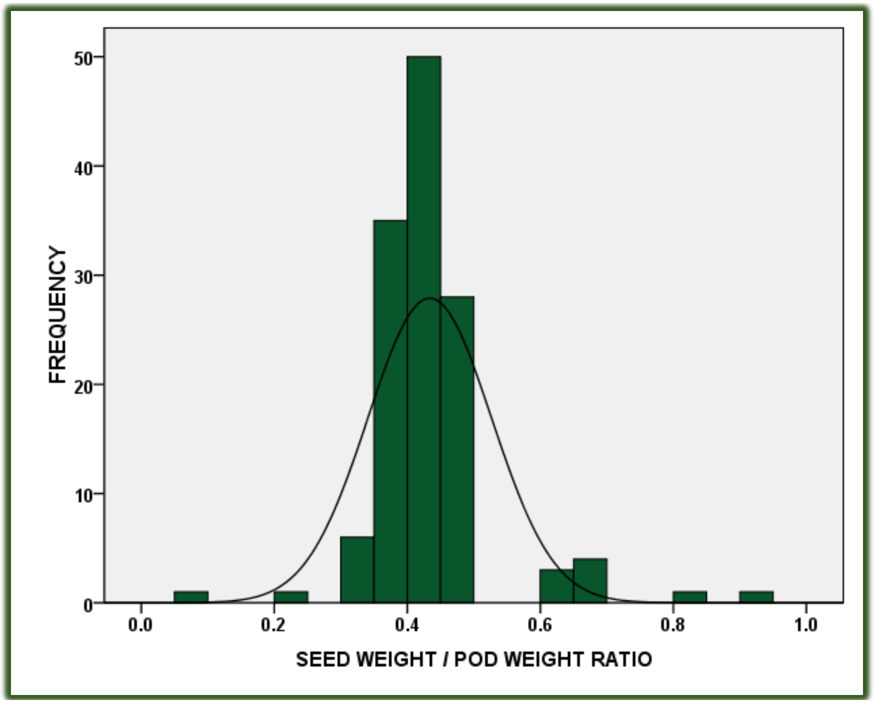


Fig. 4. Mean single seed weight (mg) for 130 pods of *V. nilotica* ssp. i*ndica*. The mean seed weight in pod was minimum (49.48 mg) in pod # 100 and maximum (181.36 mg) in pod # 98.

Seed yield per pod

The amount of seeds recovered from the pods varied from 0.5948g per pod to 2.3864g per pod (CV: 19.5%). The distribution was apparently somewhat skewed negatively and leptokurtic (Fig. 2) but tended to be normally distributed as KS-z = 0.945 was insignificant ($p < 0.334$). The seed weight recovered from the pods averaged to 1.0689 ± 0.0275g per pod.



N = 130
Mean = 0.4337
SE= 0.008153
Median = 0.4263
Mode = 0.4250
CV (%) = 21.43
G1= 1.749
Sg1 = 0.212
G2 = 9.330
Sg2 = 0.422
Minimum= 0.0763
Maximum = 0.9007
KS-z =2.5050
P < 0.001

Fig. 5. Frequency distribution of seed weight (g) / pod weight (g) ratio.

Brood size

The brood size was here determined following Uma Shaanker (1988) as the number of normal seeds in a pod which averaged to 11.208 ± 0.1694 seeds per pod varying from 5 to 15 per pod (CV: 17.24%). This parameter was found to be significantly negatively skewed and didn't follow the normal distribution (Fig. 3).

Afsar Uddin and Khan (2015) reported brood size in sixty healthy pods of *Vachellia nilotica* (possibly ssp. *nilotica*) from Karachi to be 11.23 ± 0.295 seeds per pod varying c 20.36%. Brood size distribution, however, tended to be symmetrical around the mean. For 200 all types of pods studied (pods containing normal as well as shriveled seeds, deformed, fungus-infected or insect-eaten seeds etc.), the mean brood size in *V. nilotica* averaged to 9.39 ± 0.22 seeds per pod varying around 32.48%. The brood size distribution was found to be negatively skewed. Uma Shaanker *et al.* (1988) have reported brood size in Acacia nilotica (*V. nilotica)* to be 7.44, from India (site and environment not mentioned). It follows from the results that brood in *Vachellia* appears to be a function of complex environmental conditions including fungal and insect attack as well.

The negatively–skewed distribution of brood size as found in species in hand is a common feature of many multi-ovulated species (Lee and Bazzaz, 1982). Our results follow the pattern of brood as suggested by Uma Shaanker *et al.* (1988) i.e. negatively skewed brood distribution in fruits. *Vachellia* has many-seeded fruits and majority of ovules (> 90%) within the ovary mature into seeds in most fruits as is suggested by very high seed number - mericarp number ratio in this species (Afsar Uddin and Khan, 2015). There are examples that some species accomplish the negatively skewed brood size through a maternally regulated pre-fertilization inhibition of pollen grains germination by the stigma (Ganashaiah *et al.*, 1986, 1988). In *Leucaena*, for example the germination of pollen grains is inhibited by the stigma unless a minimum threshold number of pollen tubes is deposited. This leads to a negatively skewed distribution of fertilized ovules. A similar mechanism has also been reported in *Tammarind* (Usha, 1986), *Moringa* (Uma Shaanker and Ganashaiah, 1987), and *Epilobium* (Snow, 1986). This probably ensures the development to maturity of those flowers that receive a single load of pollen grains from a particular parent. Detailed discussion on negatively skewed distribution is given in Uma Shaanker *et al.*, 1988). *Tamarindus indica* L., is, however, reported to exhibit positively–skewed distribution of brood size per pod (Thimmaraju *et al.*, 1989).

If other things are equal, the maternal parent should be selected to favour a negatively skewed distribution of brood size (Ganashaiah *et al.*, 1986; Lee, 1984). Further elucidation of brood size patterning in *V. nilotica* ssp. *indica* needs further investigation.

Mean Single seed weight in a pod (MSSW)

MSSW distributed asymmetrically, being higher than the grand mean weight in 72 cases and lower than the grand mean weight in 58 cases (Fig.4).

Seed weight / Pod weight

The seed weight: pod weight ratio averaged to 0.4337 ± 0.0082 varying from 0.0763 to 0.9007 (CV: 21.43%) (Fig.5). It exhibited great degree of leptokurtosis. It follows that in this species some more biomass is allocated to vegetative tissues like pericarp.

Individual seed weight distribution

The mean individual seed weight for a sample of 1411seeds averaged to 143.51 ± 0.751mg and varied from 3.40 to 205.30 mg (CV: 19.65%). The distribution was found to be non-normal and substantially negatively skewed and leptokurtic (Fig. 6). The seed weight of large number of seeds concentrated around the size class of 150 mg.

Our estimate of individual seed weight was substantially lower ($t = 13.48$, $p < 0.0001$) than the seed weight (177.4 ± 2.40mg, varying from 110.4 to 249.0mg) reported by Shaukat *et al.* (1999) for a sample of 200 normal sorted seeds of *Vachellia* (Acacia) *nilotica* ssp. *indica* from Gharo, District Thatta Sindh (Table 2). The seed weight in our studies, even in case when seeds lower than 110 mg in weight were excluded, happened to be 150.494 ± 0.4757mg, quite lower ($t = 10.99$, $p < 0.0001$) than that reported by Shaukat *et al.* (1999). It appears to be due to considerable number of seeds larger than 200.0 mg in their sample of 200 sorted seeds and negligible number of seeds in this class in our studies. Moreover, no seed lower than 110 mg was included in their study. Of course, a number of ecological factors may influence the mean seed size of a plant. Here, it appears that the plant thrived in better conditions in Gharo than Nauraja at least at particular time when studied.

Our estimate of seed weight was, on the other hand, quite higher than the mean seed weight (123.58 ± 1.19mg) reported for a lot of 200 seeds of *Vachellia nilotica* (probably subsp. *nilotica*) from Karachi (Afsar Uddin and Khan, 2015) and mean seed weight for a sample of 2393 seeds of *Albizia lebback* (123.03 ± 0.081mg (Afsar Uddin and Khan, 2016). The species in hand showed seed size more or less equal to that of Australian Acacias (*A. stenophylla* and *A. coriacea* ssp. *pendens*) (Khan and Sahito, 2013a; Khan *et al.*, 2013). However, *Leucaena leucocephala* is comparatively much light-seeded (Khan *et al.*, 2016) and *Erythrina suberosa* seeds are very much heavier in size (Khan *et al.*, 2014) (Table 2).

Harper (1970) opined that seed weight was the least plastic character. There are, however, reports of seed weight variation in several tropical species (Janzen, 1977; Foster and Janson, 1985; Khan *et al.*, 1984; Khan and Uma Shaanker, 2001; Murali, 1997; Marshall, 1986; Upadhaya *et al.*, 2007, Khan *et al.*, 2011). Seed weight variations within a species and an individual (Halpern, 2005) and even within a fruit of an individual (as recorded in this study) are common. Seed weight variation in plants may be many-fold in magnitude (Zhang and Maun, 1990). Sachaal (1980) found 5.6 fold variation among 659 seeds collected from a population of *Lupinus texensis*. The seeds of *Prosopis juliflora* varied in weight by 16.83% (Khan *et al.*, 1984). 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. Seed weight variation in sage brush is reported to lie between 26.31 and 31.75% amongst the sites and years of study, respectively (Busso and Perryman (2005). Seed weight is highly variable in *Alliaria petiolata* (8-fold among populations, 2.5 – 7.5-folds within population, two-three folds within individuals and 1.4 – 1.8 folds within fruits (Susko and Lovett-Doust, 2000). Halpern (2005) reported seed mass in 5839 seeds of 59 maternal plants of *Lupinus perennis* to be highly variable (5-fold variation). Sixteen-fold variation in seed mass is reported in *Lamatium salmoniflorum* (Thompson and Pellmyr, 1989).

Seed size variation may be the result of many factors (Fenner, 1985; Wulff, 1986; Mendez, 1997). Winn (1991) has suggested that plants may not have the capability of producing a completely uniform seed weight simply as a result of variation in resource availability (e.g., soil moisture during seed development). 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). Different shrubs of *Purshia tridentata* (Rosaceae) are reported to produce seeds of different mean weights as did different sites (Krannitz, 1997). Most of the variation in seed weight was attributable to variation within individual shrubs (63.2%) where different shrubs accounted for variation by 29% (Krannitz, 1997). Howe and Richter (1982), however, demonstrated variation in seed size among plants to be more than the variation within plants in case of *Virola* *surinamensis*. Variation of seeds in a tropical plant, *Pithecellobium pedicellare*, was almost similar to that in *Virola* (Kang *et. al.*, 1992). In contrast *to P. pedicellare* and *V. surinamensis*, the studies conducted intemperate zone had shown variation in seed size within plants to be greater than among plants (Sachaal, 1980; Thompson, 1984; Mazer *et al.*, 1986; Mc Ginley *et. al.*, 1990). Seed weight variation in plants thus appears universal which may be due to trade-off of resource allocation between seed size and number (Venable, 1992) or environmental heterogeneity (Janzen, 1977) or the genetic reasons. Alonso-Blanco *et al.* (1999) have indeed identified several gene loci responsible for natural genetic variation in seed size in *Arabidopsis thaliana*. Doganlar *et al.* (2000) have presented seed weight variation model in tomato.

Seed weight distribution in *V. nilotica* was found to be asymmetrical (negatively skewed). Three types of seed weight distributions (negatively-skewed, positively-skewed and normally-distributed) have been reported in literature. Seed weight distribution was found to be normal in six sunflower cultivars viz. S-278, local, Hysun 39, Hysun 33, Aussie gold 61 and Aussie gold 04 and Non-normal in NK Armoni, Hybrid 1, Aussie gold 61 and the pooled sample of all cultivars (Khan *et al.*, 2011). Seed mass was also reported to be normally distributed in *Blutapason portulacoides* and *Panicum recemosum* (Cardazzo, 2002). Halpern (2005) reported normal distribution of seed mass in *Lupinus perennis*. Zhang (1998) has reported seed mass variation in *Aeschynomene americana* by weighing 150 seeds from each of its 72 populations to be normally distributed in 9, positively skewed significantly ($p < 0.05$) in 14 and negatively skewed in 49 populations.

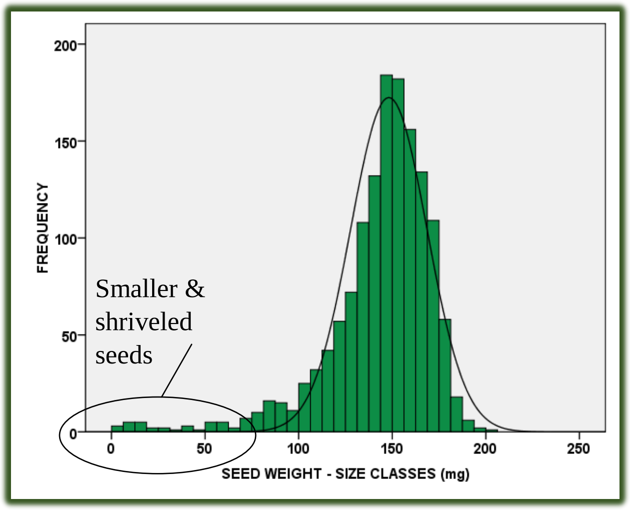
Seed size variation has been shown to have several important ecological implications. Seed mass is associated with seed germination (Baskin and Baskin, 1998; Navarro and Guitan, 2003), seedling vigour and survival, with both across species and within species (Manga and Sen, 1996; Shaukat *et al.*, 1999; Walters and Reich, 2000; Vaughan and Ramsey, 2001; Halpern, 2005) presumably reflecting the amount of reserves available for early seedling growth (Castro *et al.*, 2006). Heavier seeds produce heavy seedling with rapid pre-photosynthetic growth (Unival *et. al.*, 2008). Contrary to it, in some plants, larger seeds are not reported to give higher germination rate. In *Glycine max*, the higher rate of germination was found to be related to smaller seeds (Tiwari *et al.*, 1982). For some species carry over effects of seed size have been reported e.g., Ahmed and Zuberi (1973) reported in *Brassica compestris* L. var. *toria* that plants originating from smaller seeds produced smaller seeds than those originating from larger seeds. Larger seeds of *Telfaria occidentalis* are reported to be better adapted to cotyledon damage (Iortsuun *et al.*, 2008). In short, seed size variation produces variation in seedling fitness and thus the survival (Shaukat *et al.*, 1999) in variable environment.

Table. 1. Seed packaging costs (g) in 130 pods of *V. nilotica* subsp. *indica*.

Parameters	SPC 1	SPC 2
N	130	130
Mean	0.1986	1.4464
SE of mean	0.00578	0.08978
Median	0.195819	1.34589
CV (%)	33.18	70.77
Skewness	2.619	8.906
SE of skewness	0.212	0.212
Kurtosis	21.439	92.61
SE of Kurtosis	0.422	0.422
Minimum	0.0162	0.1103
Maximum	0.6767	12.103
KS-z	1.885	3.309
P	0.002	0.0001

SPC1, seed packaging cost (g per seed) and SPC 2, Seed packaging cost per g seeds.

MSSW, in our studies, was found to be distributed asymmetrically (positively-skewed), being higher than the grand mean weight in 72 cases and lower than the grand mean weight in 58 cases. Under controlled environmental conditions, Thompson (1984) has reported the distribution of mean seed weight in *Lamatium grayi* (Umbelliferae) around the grand mean of seed to be non-skewed and significantly leptokurtic. Differences in mean seed weight in different fruits has been suggested due to differences in environmental conditions e.g., nutrients, light, water or salinity level to which individual mother plants could have been subject during recent period of floral development and growth and seed development and maturation (Gutterman, 1992). Drought during pod filling significantly affects seed weight in *Acacia* species (Gaol and Fox, 2002). In brief, resource availability commonly limits fecundity (Fenner and Thompson, 2005). Since Smith and Fretwell (1974) model predicts optimum seed size expected in a particular ecological context, different optima for different individuals of a species may be expected. This concept may probably be extended to fruits of an individual tree where different optima may occur for different fruits produced on a tree over a period of time and internal and external environmental forces may differentially interact with different fruits developing over time as suggested by Khan and Sahito (2013).



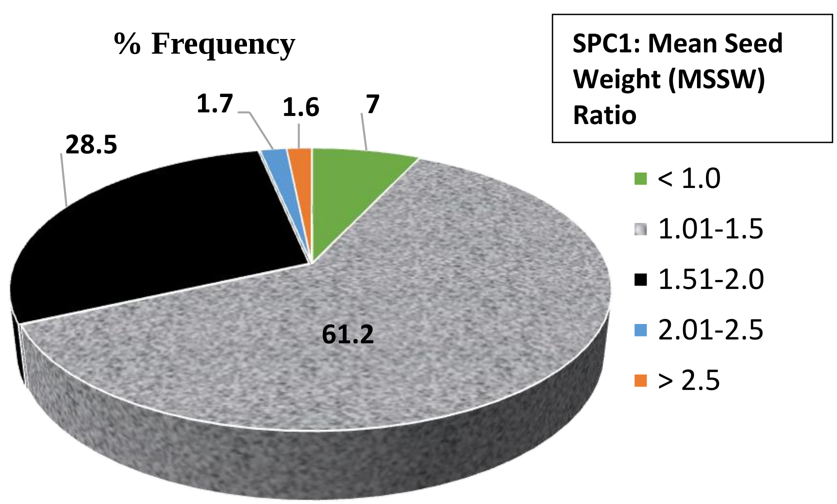
N = 1411
Mean = 143.501
SE= 0.75063
Median = 148.60
CV (%) = 19.65
G1= -1.819
Sg1 = 0.065
G2 = 5.157
Sg2 = 0.130
Min. = 3.40
Max. = 205.3
KS-z = 4.255
P < 0.0001

N = 1272*
Mean = 150.50
SE = 0.4757
Median = 151.0
CV = 11.27%
G1 = -0.140
Sg1 = 0.069
G2 = -0.446
Sg2 = 0.137
Min. = 110.4
Max. 205.30
KS-z = 0.853
P < 0.461

Fig. 6. Frequency distribution of individual seed weight (mg). The curve showed great degree of negative skewness and leptokurtosis. However, the weight of great number of seeds concentrated around the size class of 150mg. *, Descriptive statistics based on seed lot excluding 139 seeds lesser than 110mg in weight (the minimum seed size reported in Shaukat *et al.* (1999).

Seed packaging cost

The seed packaging cost on the basis of per seed (SPC1) averaged to 0.1986 ± 0.0058g per seed whereas seed packaging cost on the basis of per g seeds (SPC2) averaged to 1.4464 ± 0.0898g per g seeds. Both SPC1 and SPC2 deviated significantly from the normal distribution (Table 1). Both parameters were distributed asymmetrically (positively-skewed) and greatly leptokurtic. The packaging cost on per seed basis was in most of the pods larger than the mean seed weight for the pod. The biomass investment was thus more in pericarp than in the seed (Fig. 7).



N = 129 pods
Mean =1.3583
SE = 0.03485
Q2 = 1.3339
CV = 29.14%
G1 = 0.941
Sg1 = 0.213
G2 = 9.577
Sg2 =0.423
Minimum= 0.1102
Maximum = 3.671
KS-z = 1.728
P < 0.005

Fig. 7. Frequency distribution of SPC1: mean seed weight ratio in 129 pods of *Vachellia nilotica* ssp. *indica*. One pod yielding one normal seed (159.5mg) and nine very smaller seeds was excluded as outlier

The seed packaging cost varied among the local legumes substantially. It was much higher in indehiscent pods of *C. fistula* with large amount of mesocarpic pulp and in tardily dehiscent pods of D*elonix regia* with thicker and hard pericarp (Table 2) but quite low in *Leucaena leucocephala* presumably owing to its thin and lighter pericarp and larger brood size. SPC1 in *Albizia lebback* was little higher than in *Vachellia* spp. The magnitude of SPC2 was quite higher than SPC1except in case of *Erythrina suberosa* where SPC2 was not as higher obviously due to larger seed size (c. 686.5 mg) in *E. suberosa*. It is obvious that the bionomic aspects of the packaging costs demand larger number of seeds to be packed in a fruit so that SPC is reduced (Bookman, 1984; Corner, 1957; Ganashaiah *et al.*, 1986, Janzen, 1982).

Table. 2. Seed packaging costs and single seed weight of some leguminous plants of Sindh.

Species	SPC1 (g per seed)	SPC2 g per g seeds)	Seed Weight (mg)	Reference
Vachellia nilotica				
Mother Plant A	0.2011	1.7398± 0.1722	123.58 ±1.19	Afsar Uddin and Khan (2015)
Mother Plant B	0.2021	1.7107 ± 0.1721		
Acacia stenophylla	0.2495 ± 0.0108	2.3732 ± 0.1160	139.49 ± 0.94 (29.9-201.6)	Khan and Sahito (2013a)
Acacia coriacea ssp. *pendens*	0.4277 ± 0.0231	3.6400 ± 0.2201	139.7 ±1.09 (58.4-243.7)	Khan *et al.* (2013)
Albizia lebback				
Mother Plant A	0.2647 ± 0.1233	2.2940 ±0.1488	123.03 ± 0.81 14.0- 245.0)	Afsar Uddin and Khan (2016)
Mother plant B	0.2965 ± 0.0103	2.4145 ± 0.0149		
Mother Plant C	0.2923 ± 0.0234	2.8150 ± 0.0302		
Cassia fasciculata	0.0765 ± 0.0514	--	--	Willson *et al.* (2010)
Cassia fistula	0.7672 ± 0.0514	6.961 ± 0.4610	109.5 ± 3.1 46.5-150.0)	Khan and Zaki (2012)
Cassia holosericea	--	--	15.68 ± 0.229	Khan and Shaukat (1990)
Delonix regia	4.5493 ± 0.1882	11.912 ± 0.5292	397.39 ± 3.94 (55.8-638.1)	Khan and Sahito (2013b)
Erythrina suberosa	0.4959 ± 0.0245	0.7479 ± 0.0420	686.49 ± 7.29 (51.0-987.6)	Khan *et al.* (2014)
Leucaena leucocephala				
Mother Plant A	0.0305	0.7497 ± 0.0458	39.21 ±0.112 (3.79-96.8)	Khan *et al.* (2016)
Mother Plant B	0.0350	0.9798 ± 0.0027		
Mother Plant C	0.0306	0.7799 ± 0.0357		
Vachellia nilotica ssp. indica	--	--	177.4 ± 2.40	Shaukat *et al.* (1999)
Vachellia nilotica ssp. *indica*	0.1986 ± 0.0058	1.4462 ± 0.0698	143.51 ± 0.75	Present study

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