Int. J. Biol. Res., **6(1): 35-42, 2018.**

SEED MASS VARIATION IN SOAPNUT - *SAPINDUS TRIFOLIATUS* L.

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ABSTRACT

The data based on 163 trilobed berries of *Sapindus trifoliatus* L. indicated that brood size of this species is predominantly one seed per berry (80.98%) but often two seeds per berry may be seen (19.02%). Fruits yielding three seeds are very rare (0.61%). The mean seed weight was the function of the brood size. Although the seed yield per fruit increased with the brood size, the mean seed size declined with brood size. The mean seed weight from one-seeded fruit (mean seed = 0.68038 ± 0.00804g, N = 126) was significantly larger (t = 3.22, p<0.001) than that of two-seeded fruit (mean seed = 0.6302 ± 0.01354; N= 54) by 50.28mg and also significantly larger (t = 3.7.778, p<0.001) by a similar quantum of 50.6mg from a mean seed of three-seeded fruit (mean seed = 0.6298 ± 0.01437g; N = 3). There was no significant difference between mean seed weights of two-seeded and three-seeded fruits (t = 0.189, NS). The low proportion of occurrence of two-seeded fruits, however, may presumably due to some impediments to the ovular development or the second event of fertilization. Further research is needed to elucidate the reproductive eco-physiology of the species.

KEYWORDS: Seed weight, Brood-size, *Sapindus trifoliatus*.

INTRODUCTION

'*Sapindus*' is a tropical and subtropical genus of Fam. Sapindaceae. This genus comprises 13 species distributed mainly in America, the Pacific Islands and Asia. Three species of *Sapindus* are reported from Pakistan – *S. mukorossi* Gaertn., *S. trifoliatus* Linn. and *S. emarginatus* Vahl. (Abdulla, 1973). This paper relates with the seed mass variation of *S. trifoliatus*, not so common species in Pakistan but very important tropical agro-forestry tree. It is a hard wood tree, economically quite useful. It contains a number of phytochemicals and medicinally very important and commonly used in Ayurvedic system of medicine - in birth control (as pregnancy interceptive) (Goyal *et al.,* 2014; Pal *et al.,* 2013). It is potential anthelmintic (Saravanti *et al*., 2011) and anti-ulcer (Kishore *et al.,* 2011). It is potential biodiesel source (Ariharan *et al.,* 2015).

The present studies report the variation of seed mass in *S. trifoliatus* with respect to the brood size of the fruits.

MATERIALS AND METHODS

One hundred and sixty three (163) healthy mature berries (Fig. 1a) of *Sapindus trifoliatus* were collected from a mature large tree growing in the Campus of the Karachi University, Karachi, Pakistan in June, 2007. The fruit were graded into three categories – One-seeded, two-seeded and three- seeded. The seeds recovered from these fruit types were kept in separate vessel and weighed individually on electric balance. The data were analyzed for descriptive high order statistics. The statistical package employed was SPSS ver. 17. Normality of data distribution was tested with Kolmogorov-Smirnoff z (K-S z), Kolmogorov-Smirnoff test (K-S test*) corrected for Lilliefors significance correction (Dallal and Wilkinson, 1986; Neter *et al.,* 1988) and Shapiro-Wilk test (Shapiro and Wilk, 1965). Thode (2002) has opined that KS-z suffers from its low power to detect normality and should no more seriously be considered for testing normality.

RESULTS AND DISCUSSION

The seeds of *S. trifoliatus* are black, hard and smooth enclosed in berries. Each berry is a tri-lobed structure (Fig. 1a). The brood size varied from one to three seeds per fruit. Of three lobes, generally only one lobe is large and fertile, other two lobes are smaller and devoid of seeds in most of the cases. In our studies out of 163 fruits, 132 fruits (80.98%) yielded one seed, 31 fruits (19.02%) yielded two seeds and only 01 fruit (0.61 %) yielded three seeds (Fig. 1b). The seed size in fruits varied considerable in fruits as given below.

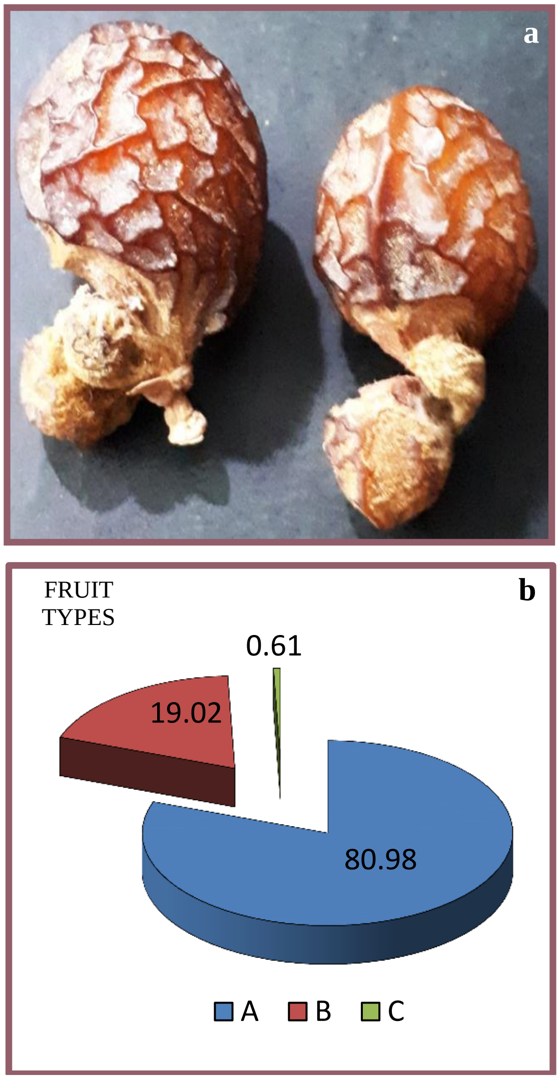
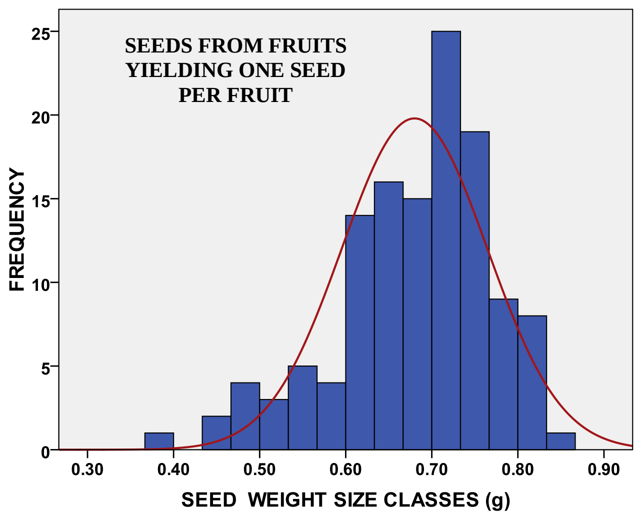


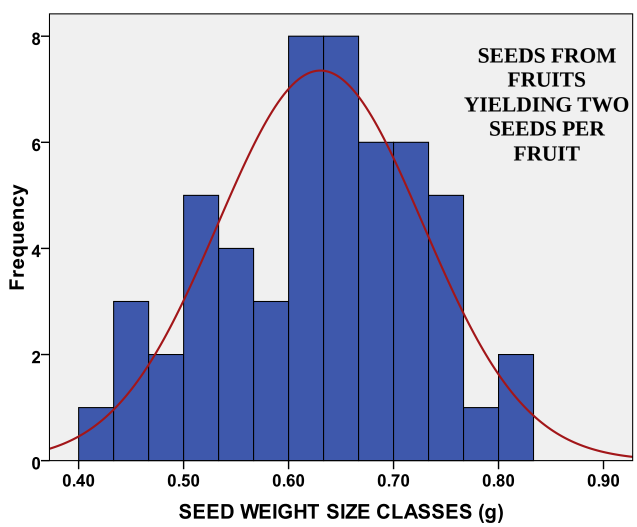
Fig. 1. *Sapindus trifoliatus*. a, Fruits with differentially-sized lobes; b, Percent proportion of fruits yielding one, two and three seeds per fruit. A, One-seeded fruits; B, Two-seeded fruits and C, Three seeded fruits.



One-seeded Fruits

N = 126 Seeds
Mean = 0.6804 g
SE = 0.0080364
Median = 0.6945
CV (%) = 13.26
G1 = - 0.842
Sg1 = 0.216
G2 = 0.706
Sg2 = 0.428
Minimum = 0.3798
Maximum = 0.8560
KS-z = 1.124
P < 0.159
K-S test* = 0.100
P < 0.003
Shapiro-Wilk = 0.954
P < 0.0001

Fig. 2. Frequency distribution of seed mass of seeds recovered from one-seeded Fruits of *S. trifoliatus* L. *, K-S test corrected on the basis of Lilliefors significance correction.



Two-seeded Fruits

N = 54 Seeds
Mean = 0.6302 g
SE = 0.013538
Median = 0.6350
CV (%) = 15.78
G1 = - 0.300
Sg1 = 0.325
G2 = - 0.584
Sg2 = 0.639
Minimum = 0.4000
Maximum = 0.8187
KS-z = 0.671
P < 0.724
K-S test* = 0.099
P < 0.200
Shapiro-Wilk =0.975
P < 0.330

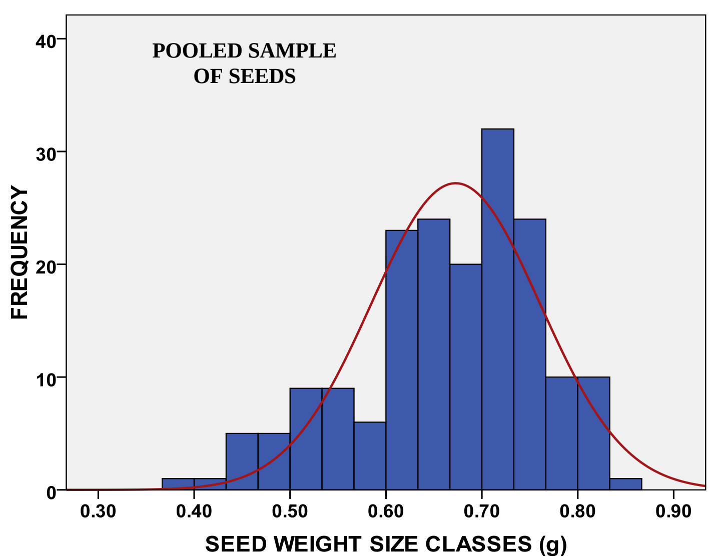
Fig. 3. Frequency distribution of seed mass of seeds recovered from two-seeded fruits of *S. trifoliatus* L. *, Corrected on the basis of Lilliefors significance correction.

Seed size in one-seeded-fruits: Out of 132 one-seeded-fruits, 126 seeds recovered were phenotypically healthier (95.45%) and 06 seeds (4.54 %) were found to be damaged due to random reasons. The frequency distribution of size of these healthier seeds is presented in Fig. 2. In these fruits, individual seed weight varied from 0.3795 to 0.8560g (CV: 13.26%) averaging to 0.68038 ± 0.00804g (N = 126). The seed weight, in spite of apparent skewness (negative) and peakedness, was shown to follow normal distribution by the insignificant value of KS-z: 1.124 ($p < 0.159$). The corrected Kolmogorov-Smirnoff test on the basis of Lilliefors significance correction and the Shapiro-Wilks test, however, indicated that the sample came from the population which was not dispersed normally. This may presumably be attributed to the weakness of K-S z as normality tester (Thode, 2002). In majority of the cases (78.6%) the seed weight belonged to a size class of 0.61- 0.80g.

Seed size in two-seeded fruits: Sixty-two seeds were recovered from 31 fruits. Of these seeds, there were 08 damaged seeds. The single seed weight in two seeded fruits varied from 0.40 to 0.8187 (CV: 15.78) and averaged to 0.6302 ± 0.01354 (N= 54) (Fig. 3). The seed weight was shown to follow normal distribution due to in significance of Kolmogorov-Smirnoff z (KS-z: 0.671, p<0.724). The corrected Kolmogorov-Smirnoff test on the basis of Lilliefors significance correction and the Shapiro-Wilks test, however, indicated that seed mass sample came from the seed population which dispersed normally. In 62.8% of the cases single seed weight fell in the size class of 0.61-0.8g. As compared to the one-seeded fruits, the representation of seeds in this class was lesser by a quantum of 15.8%.

Seed size in three-seeded fruits: Three-seeded fruit was only one in number and yielded one seed from each locule. The seed weight averaged to 0.6298 ± 0.01437g (N = 3) varying from 0.6010 to 0.6640.

Seed size variation in pooled sample of seeds: The weight of single seed in the pooled sample (N = 183) averaged to 0.6647 ± 0.00702g. The sample was indicated to be negatively skewed. The sample which appeared to follow normal distribution on the basis of Kolmogorov-Smirnoff z (KS-z: 1.138, p < 0.150) was found to be non-normal on the basis of Shapiro-Wilks test and Lilliefors correction of Kolmogorov-Smirnoff test (Fig. 4). As given by coefficient of variability (CV) the seed weight varied by 14.29 % (2.25-folds). It appears that seed weight distribution in *S. trifoliatus* should be re-examined on the basis of larger sample size.



Pooled sample of Seeds

N = 183 Seeds
Mean = 0.6647 g
SE = 0.0070215
Median = 0.680
CV (%) = 14.37
G1 = - 0.647
Sg1 = 0.180
G2 = 0.055
Sg2 = 0.357
Minimum = 0.3798
Maximum = 0.8560
KS-z = 1.138
P < 0.150
K-S test* = 0.084
P < 0.003
Shapiro-Wilk = 0.965
P < 0.0001

Fig. 4. Frequency distribution of seed mass of seeds recovered from Fruits (pooled sample) of *S. trifoliatus* L.*, Corrected on the basis of Lilliefors significance correction.

According to Kundu *et al.* (2015) there exists large variation in seed weight of *S. trifoliatus* - 1000-2500 seeds of weigh around one kg i.e. weight of one seed may vary between 400 and 1000 mg. In this respect much work has been done on *Sapindus mukorossi*, which appears to be comparatively large-seeded species. The 100- seed weight *of S. mukorossi* from Southern China provinces is reported to vary between 81.57 to 238.52 g (CV: 25%) averaging to 139.55 ± 35.45 (SD) (Sun *et al.,* 2017) corresponding on an average to 1395.5 mg per seed. Geographic variation of seed weight in *S. mukorossi* is also reported by Kairon and Sankhyan (2017) amongst various localities of Himachal Pradesh, India – 100-seed weight varying from 138.77 to 226.05g corresponding to 1388 to 2260mg per seed. Attri *et al.* (2011) have reported seed weight variation in phenotypically healthy trees of this species in Himachal Pradesh (India) to be 121.30 to 210.232g per 100 seeds i.e., 1213 to 2102mg per seed.

It may be inferred that although the seed yield per fruit increased with the brood size but the mean seed size declined. By above-given data, it is obvious that a mean seed weight from one-seeded fruit was significantly larger ($t = 3.22$, $p<0.001$) than that of two-seeded fruit by 50.28mg and also significantly larger ($t = 3.7.778$, $p<0.001$) by a similar quantum of 50.6mg from a mean seed of three-seeded fruit. However, there was no significant difference between mean seed weight of two-seeded and three-seeded fruits ($t = 0.189$, NS). The variation in single seed weight in one-seeded fruits (13.26% or 2.25-folds) and that in two-seeded fruits (15.78 or 2.05-folds) was more or less comparable. Seed weight variation has been reported in several tropical species (Janzen, 1977; Foster and Janson, 1985; Khan *et al.*, 1984; Michaels *et al.*, 1988; Khan and Zaki, 2012; Khan and Sahito, 2013 a and b; Khan and Uma Shaanker, 2001; Murali, 1997; Marshall, 1986; Upadhaya *et al.,* 2007; Khan *et al.,* 2013, 2014, 2016; Afsar uddin and Khan, 2016). Seed weight variations within a species and an individual (Halpern, 2005) and even within a fruit of an individual is a common phenomenon (Khan *et al.,* 2018). According to Andres-Augustin *et al.* (2006) coefficients of variation of 12% or less are acceptable in characterizing plant organ (s) in horticultural species and it would be desirable to increase the sample size if this ratio is higher. In our studies seed weight in berries had variability below or near equal to 15%.

As regards to the distribution of seed weight all three types of seed weight distributions (negatively-skewed, positively-skewed and normal non-skewed) have been reported in literature. Afsar uddin and Khan (2016) reported negatively- skewed seed weight distribution in *Albizia lebback*. Seed mass distribution was found to be to be normal in some cultivars of sunflower and non-normal in other cultivars of sunflower (Khan *et al.,* 2011). Seventy two populations of *Aeschynomene americana* were studies for seed weight distribution by Zhang (1998). The distribution was normal in 9 populations, positively skewed in 14 and negatively skewed in 49 populations.

Seed mass variation, besides genetic reasons (Alonso-Blanco *et al.*, 1999; Doganlar *et al.,* 2000), may be the result of many other factors (Fenner, 1985; Fenner and Thompson, 2005; Wulff, 1986; Mendez, 1997) influencing resource availability. Seed weight variation in plants appears universal which may be due to trade-off of resource allocation between seed size and seed number (Venable, 1992) or environmental heterogeneity (Janzen, 1977). Seed mass variation has been shown to have several important ecological implications. Seed mass is associated with seed germination (Baskin and Baskin, 1998), 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).

The decline of mean seed weight in two-seeded fruits may in part be due to the competition for nutrients between the developing seeds and the time lag phenomenon between the successive events of fertilization of two ovules. The low proportion of occurrence of two-seeded fruits, however, may presumably be due to some impediments to the ovular development or to the second event of fertilization.

Wool (1980) has opined that high order statistics like measure of skewness and kurtosis may be helpful to identify canalized characters with some degree of confidence and to indicate how the distribution of a character is modified in different environments. Canalization as proposed by Waddington (1957) is the developmental suppression of the effects of genetic and environmental perturbations on the expression of phenotype (say seed mass). Fraser's (1977) theory predicted that the distribution of a canalized character (s) could yield information about the niche breadth of the species. Under evolutionary norm, the distribution of a canalized character should be leptokurtic, symmetrical and provided with low variance. The distribution should be skewed if deviation from the normal environment (of the organism) is "slight" and distribution should be normal with large variation if departures from the normal environment are large. That is to say that the range of the environments which can be classified as normal is a measure of the niche breadth. In the present studies, independent knowledge of degree of canalization of such character as weight of individual seed is not available but it appears logical to accept that seed mass in *S. trifoliatus* is most likely a canalized character provided with low coefficient of variability. The distribution of seed weight in the present study being significantly negatively skewed, mesokurtic and provided with a coefficient of variability of the order of 14.37% indicate that in-hand individual of *S. trifoliatus* is growing under environmental conditions somewhat deviating from the norm. Further research is undoubtedly needed to elucidate the reproductive eco-ecology of the species.

REFERENCES

Abdulla, P. (1973). Sapindaceae. *Flora W. Pakistan* 39: 1-10.

Afsar Uddin and D. Khan. (2016). Variation in fruit-, brood- and seed-size and seed packaging cost in *Albizia lebbeck* (L.) Benth. *FUUAST J. Biol*., 6(2): 181-199.

Alonso-Blanco. C., H.B. Vries, C.J. Hauhart and M. Koornneef. (1999). Natural allelic variation at seed size loci in relation to other life history traits of *Arabidopsis thaliana*. *Proc. Natl. Acad. Sci. USA*., 96: 4710-4717.

Andrés-Augustin, J., F. González-Andrés, R. Nieto-Angel and A.F. Barrientos-Priga. (2006). Morphology of the organs of Cherimoya (*Annona cherimola* Mill.) and analysis of fruit parameters for the characterization of cultivars, and Mexican germplasm selections. *Sci. Hortic*., 107: 337-346.

Ariharan, V. N., V.N. Meena Devi, N.K. Parameswaran and P. Nagaendra Prasad. (2015). Physico-chemical studies on soapnut (*Sapindus trifoliatus*) oil for source as biodiesel. *Asian J. Pharma. & Clinical Res*., 8(5): 87-89.

Attri, V., K.S. Pant, M.K. Thakur, R. Dhiman and D.P. Sharma. (2011). Effect of seed size and organic manure doses on growth and development of *Sapindus mukorossi* (Gaertn.). *J. Tree Sciences*, 30: 20-23.

Baskin, C.C. and J.M. Baskin. (1998). *Seeds Ecology, Biogeography and Evolution of Dormancy and Germination*. Academic press, New York.

Castro, J., J.A. Hodder and J.M. Gómez. (2006). Seed size .In: *Handbook of Seed Science and Technology* (A. Basra, Ed.) Haworth's food Products Press. NY. pp. 397-427.

Dallal, G.E. and L. Wilkinson. (1986). An analytic approximation to the distribution of Lilliefors' test for normality. *Am. Statistician* 40: 294-296.

Doganlar, S., A. Frary and S.D. Tanksley. (2000). The genetic basis of seed weight variation: tomato as a model system. *Theor. Appl. Genet*., 100: 4267-1273.

Fenner, M. (1985). *Seed Ecology*. Chapman and Hall., NY. 151 pp.

Fenner, M. and K. Thompson. (2005). *The Ecology of seeds*. Cambridge University Press, Cambridge, U.K.

Foster, S.A. and S.A. Jansen. (1985). The relationship between seed size and establishment conditions in tropical woody plants. *Ecology*, 66: 773-780.

Fraser, A.(1977). The use of canalized characters to specify the limits of ecological niches. Am. Natur. 111; 1986-198.

Goyal, S., D. Kumar, G. Menaria and S. Singla. (2014). Medicinal plants of genus *Sapindus* (Sapindaceae) – A review of their botany, phytochemistry, biological activity and traditional use. *J. Drug Delivery and Therapeutics*, 4(50): 7-20.

Halpern, S.L. (2005). Sources and consequences of seed size variation in *Lupinus perennis* (Fabaceae): adaptive and non-adaptive hypotheses. *Am. J. Bot*., 92(2): 205-213.

Halpern, S.L. (2005). Sources and consequences of seed size variation in *Lupinus perennis* (Fabaceae): adaptive and non-adaptive hypotheses. *Am. J. Bot*., 92(2): 205-213.

Janzen, D.H. (1977). Variation in seed weight in Costa Rican *Cassia grandis* (Leguminosae). *Tropical Ecology,* 18: 177-186.

Janzen, D.H. (1982). Variation in average seed size and fruity seediness in a fruit crop of a Guanacaste tree (Leguminosae) *Enterolobium cyclocarpum. Am. J. Bot*., 69: 1169-1178.

Khairon, V.K. and H.P. Sankhyan. (2017). Genetic variability in soapnut (*Sapindus mukorossi* Gaertn.) among different seed sources in Himachal Pradesh. *Int. J. Chemical Studies,* 5(2): 471-476.

Khan, D. and M.J. Zaki. (2012). Pods and seeds characteristics within a pod crop of an Amaltas tree (*Cassia fistula* L. – Caesalpiniaceae): insect infection, number of seeds per pod and the seed packaging cost. *Int. J. Biol. Biotech.,* 9(1-2): 31-50.

Khan, D. and Z.A. Sahito. (2013a). Variation in pod- and seed sizes and seed packaging cost in *Acacia stenophylla* A. Cumm. Ex Benth.- an Australian Wattle growing in Karachi, Pakistan. *FUUST J. Biol.,* 3(1): 15-30.

Khan, D. and Z.A. Sahito. (2013b). Maternal investment of biomass in pods and seeds and seed packaging cost in *Delonix regia* (Bojer) Rafin (Caesalpiniaceae). *Int. J. Biol. Res.,* 1(2): 105-114.

Khan, D., Afsaruddin and M.J. Zaki. (2016). Variation in brood- and seed-size and seed packaging cost in *Leucaena leucocephala (*Lam.) De Wit from Karachi. *Int. J. Biol. Biotech.,* 13(1): 115-130.

Khan, D., M. Anis and M.J. Zaki. (2011). Seed mass variation in seed lots of nine cultivars of sunflower (*Helianthus annuus* L.). *Int. J. Biol. & Biotech*., 8(2): 263-273.

Khan, D., S.S. Shaukat and M. Faheemuddin. (1984). Germination studies of certain desert plants. *Pak. J. Bot*., 16: 231–254.

Khan, D., Z.A. Sahito and M. Javed Zaki. (2018). 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. *Int. J. Biol. Biotech.,* 15(3): 493-503.

Khan, D., Z.A. Sahito and M.J. Zaki. (2013). Parental investment of biomass in pod, seed and seed packaging in tree of wiry wattle (*Acacia coriacea* subsp. *pendens*) growing in Karachi, Pakistan. *Int. J. Biol. Biotech.,* 10(4): 515-536.

Khan, D., Z.A. Sahito, M.J. Zaki and S.S. Shaukat. (2014). Axial dimensions of pods and seeds and within-pod-allocation of phytomass and seed packaging cost in *Erythrina suberosa* Roxb. (Papilionaceae). *Int. J. Biol. Biotech*., 11(2-3): 191-206.

Khan, M.L. and R. Uma Shaanker. (2001). Effect of seed weight, light regime, and substratum microsite on germination and seedling growth of *Quercus semiserrata* Roxb. *Trop. Ecol*., 42: 117-125.

Kishore, D.V., P. Jennifer and K.V. Mini. (2011). Antiulcer activity of methanolic and aqueous extracts of leaves of *Sapindus trifoliatus* Linn. *Int. J. Pharm. Sci. Review & Res*., 6(1): 25-27.

Kundu, M., Mailtreyee, L.H. Schmidt and L. Holger. (2015). *Sapindus trifoliatus* L. Seed Leaflet 162. University of Copenhagen.

Manga, V.K. and D.N. Sen. (1996). Genetics parameters for seed traits in *Prosopis cineraria* (L.) Macbirds. *Indian J. Forestry,* 19: 148-151.

Marshall, D.L. (1986). Effect of seed size on seedling success in three species of *Sesbania* (Fabaceae). *Am. J. Bot*., 73: 457-464.

Méndez, M. (1997). Sources of variation in seed mass in *Arum italicum. Int. J. Plant Sci.,* 158(3): 298-305.

Murali, K.S. (1997). Pattern of seed size, germination and seed viability of tropical tree species in southern India. *Biotropica*., 29: 271-279.

Neter, J., W. Wasseman and G.A. Whitmore (1988). *Applied Statistics.* III Ed. Boston Allyn and bacon ltd.

Pal, R., A. Mukherjee and A. Saha. (2013). Exploring post coital Anti-fertility activity with toxicological and hormonal profiling of *Sapindus trifoliatus* L. *Int. Res, J. Pharma. Appl. Sci*., 3(5): 53-60.

Saravanti, K.C., S. Srilakhshmi and M. Sarvani. (2011). Anthelmintic activity of *Sapindus trifoliatus* seed extract. *Int. J. Pharm. & Technology*, 3(1): 1603-1608.

Shapiro, S.S. and M.B. Wilk (1965). An analysis of variance test no0rmailty. *J. Am. Stat. Assoc*. 67: 215-216.

Shaukat, S.S., Z.S. Siddiqui and S. Aziz. (1999). Seed size variation and its effects on germination, growth and seedling survival in *Acacia nilotica* sub sp. *indica* (Benth.) Brenan. *Pak. J. Bot*., 31(2): 253-263.

Sun, C., J. Wang, J. Duan, G. Zhao, X. Weng and L. Jhu. (2017). Association of fruit and seed traits of *Sapindus mukorossi* germplasm with environmental factors in Southern China. *Forests* 8, 491. Doi: 10.3390/f8120491 (www. mdpi.com/journal/ forests)

Thode, H.J. (2002). Testing for normality. New York: Marcel Dekker.

Upadhaya, K., H.N. Pandey and P.S. Law. (2007). The effect of seed mass on germination, seedling survival and growth in *Prunus jenkinsii* Hook. f. & Thoms. *Turk. J. Bot*., 31: 31-36.

Vaughan, G. and M. Ramsey. (2001). Relationships between seed mass and nutrients, and seedling growth in *Banksia cunninghamii* (Proteacae). *Int. J. Plant Sci*., 162: 599-606.

Waddington, C.H. (1957). The strategy of the gene. Allen and Unwin.

Walters, M.B. and P.B. Reich. (2000). Seed size, nitrogen supply, and growth rate affects tree seedling survival in deep shade. *Ecology,* 81: 1887-1901.

Wool, D. (1980). On ecological inference from kurtosis and skewness of morphological characters. Res. Popul. Ecol. 22: 263-272.

Wullf, R.D. (1986). Seed size variation in *Desmodium paniculatum* I. factors affecting seed size. *J. Ecol*., 74: 87-97.

Zhang, J. (1998). Variation and allometry of seed weight in *Aeschynomene americana*. *Annals of Botany* 82: 843-847.

(Received April 2018; Accepted June 2018)