



RESEARCH ARTICLE

Optimization of Grading Efficiency of a Specific Gravity Separator to Upgrade the Quality of (*Moringa oleifera* Lam.) Seeds

R.Chandraprakash¹, P.Masilamani², P. Rajkumar³, R. Geetha¹, V. Alex Albert⁴ and T. Eevera²

¹Agricultural College and Research institute, Madurai- 625104,

²Anbil Dharmalingam Agricultural College and Research institute, Navalurkuttapattu, Tiruchirappalli-620027,

³Tamil Nadu Agricultural University, Coimbatore-641003,

⁴Agricultural Engineering College and Research Institute, Kumulur - 621712,

ABSTRACT

The quality of *Moringa oleifera* seeds need to be ensured before sowing or using the seeds for other commercial purposes like oil extraction. In this study, an attempt was made to increase the efficiency of a specific gravity separator machine to upgrade the quality of moringa seed by suitably changing the machine settings viz., horizontal height (cm), vertical height (cm), and oscillation speed (rpm) of the deck and air blow rate (m³/hr). The optimization of moringa seed quality upgrading specific gravity machine has a horizontal height (cm), vertical height (cm), and air blow rate (m³/hr) adjustments of 0, 1.5, and 4.0 respectively at 450 rpm of deck oscillation. Under the above-optimized conditions, seed lot graded into five categories viz., A, B, C, D and E. Germination percentage of three grade viz., C, D, and E have 93.0%, 97.0%, and 96.0% respectively, which was higher than the germination percentage of ungraded bulk moringa seed lot (91.0%) used in this experiment. Seed with undesirable size and low in weight got separated as 'A' grade material. The optimization of moringa seed upgrading process showed the optimal processing conditions for grading the moringa seed based on physical property of the seed. The optimization of the moringa seed-grading machine would provide necessary information on combination of seed, operation and design parameters for enhancing seed quality.

Received : 17th August, 2020

Revised : 08th September, 2020

Accepted : 23rd September, 2020

Keywords: *Moringa seed, Germination, Gravity separator, Seed filling, Operation parameters, Design parameters*

INTRODUCTION

Moringa seeds developing at different positions on the mother plant may not have the same size, shape, weight, and germination potential. It may be due to resources are not distributed equally to all seeds. Thus, some seeds are larger than others, and large seeds may have a different level of germination potential than small ones (Datta et al., 1970; Halloran and Collins, 1974). Another possibility for differences in the weight of the seed is that pods produced at the top of the tree developed under different environmental conditions than those produced at the bottom of the tree. Also, the physiological maturity of the mother plant may vary when seeds are produced in different positions.

In some species, the position of the seed in the fruit influences seed size and vigour, and thus indirectly the expressed in the germinating seedlings. In legumes, ovules in the basal and styler ends of the fruit got affected compared to the ovules in the middle portion, particularly in *Vigna unguiculata*.

Further, Kang et al., (1993) reported that seeds developed at the middle and basal end of the fruit were heavier than those that did so at the styler end. In legumes of *Robinia pseudoacacia*, seeds at the styler end had more mass than those at the basal end, and seedlings from seeds with high mass were larger than those from seeds with low mass (Susko, 2006). In the commercial-scale moringa seed production programme at Agricultural Engineering College and Research, Institute, Kumulur, Tamil Nadu, we face a high level of polymorphism among the harvested moringa seeds regarding size, shape, and weight. In addition, seed damage is a factor arising from mechanized shelling of moringa (Fadele and Aremu, 2016) and resulted in reduction of germination due to presence of both undamaged and broken seeds in the final lot.

All the above problems necessitate the grading of moringa seed to reduce the heterogeneity and to maximize the homogeneity and quality of the final seed lot. Optimization of grading process is useful

*Corresponding author's e-mail: masil_mahes@yahoo.com

in minimizing the heterogeneity of the processed agricultural produce. This technique could be applied in maximizing parameters such as grading efficiency. Optimization of efficiency of a machine is a process of identifying the best combination of different variables with the objective of getting better output. Rashid *et al.*, (2011) optimized the transesterification process for moringa seed oil by adopting response surface methodology (RSM); Dehuller machine was optimized to reduce seed damage during removal of seed from capitulum of safflower (Figueiredo *et al.*, (2013) & (2014) and moringa (Aviara *et al.*, 2013) . Kumar *et al.*, (2016) optimized the decorticator for improving the seed decortication process.

Most researchers attempted to assess the effects of variation in sizes of seeds on grading processes. Irregularities in seed sizes should be dealt with by proper grading. However, many of the researchers expressed difficulty in establishing a workable machine setting for each size grade that will allow an acceptable balance to be achieved between the separation of damaged and undamaged seeds. Therefore, this research presents an optimal combination of operation parameters (oscillation speed (rpm) of the deck and air blow rate (m³/hr)) and design parameter (horizontal and vertical height (cm) of an oscillating deck of the machine) in the grading process of moringa seed.

MATERIAL AND METHODS

Moringa seeds of variety PKM 1 were collected from seed production field of Agricultural Engineering College and Research, Institute, Kumulur, Tamil Nadu and used for these study. Collected heterogeneous materials were graded in a specific gravity separator by adjusting the machine settings combination like horizontal height and vertical height of deck, air blow rate and deck oscillation rate. Three different combination of machine settings viz., C1 (horizontal height (0.0cm) of deck, vertical height of deck (1.0cm), air blow rate (3.5 m³/hr)), C2 (horizontal height (0.0cm) of deck, vertical height of deck (1.5cm), air blow rate (4.0 m³/hr)) and C3 (horizontal height (0.0cm) of deck, vertical height of deck (2.0cm), air blow rate (4.5m³/hr)) were tried in this experiment. After making every machine settings adjustment, seed grading was performed and all the run seeds were collected in all the five outlets, namely A, B, C, D, and E. All the collected grade-wise seeds were verified for seed recovery percentage and 100 seed weight measurement in order to find out ideal machine settings for the recovery of good quality seeds alone from the given seed lot at large scale level. Likewise, all the grades of seed samples were analyzed for seed germination as per the protocol given by the ISTA (2014). During the seed germination test, the speed of germination

(Maguire 1962), seedling length (ISTA 2014), dry-matter production (Gupta 1993), and seed vigour (Abdul-Baki and Anderson 1973) was measured.

In addition, physical and physiological quality parameters, biochemical properties like protein (Lowery *et al.*, 1951), carbohydrate (Taylor, 1995) and oil content (Natarajan *et al.*, 2003) were also measured.

Experiments were conducted in a Factorial Completely Randomized Block Design (FCRD). The results were subjected to analysis of variance and tested (t-test) for significant difference ($p=0.05$) as suggested by Panse and Sukhatme (1999). Percentage values were transformed into arc sine values prior to statistical analysis.

RESULTS AND DISCUSSION

Specific gravity separator was operated with moringa seeds in view of optimizing the machine settings to grade the moringa seeds based on their physical properties.

During each run the main parameters viz., vertical height, horizontal height, air blow rate and deck oscillation speed were adjusted for three combination of machine setting. During all the runs, seeds were collected from all the five outlets namely A, B, C, D and E.

Among the three machine settings combination viz., C1, C2 and C3 were tested, machine setting combination of C2 was found to be ideal and more specific for grading the moringa seeds. This was confirmed based on graded seed material physical, physiological and biochemical properties.

To verify the physical, physiological and biochemical parameters of the seed collected from all five outlets of specific gravity separator machine operated with optimized machine settings combination C2, experiments were conducted along with ungraded bulk seed material as a check.

In this experiment, seeds collected from the outlet D operated with the machine settings of C2 recorded significantly higher value for seed recovery percentage, 100 seed weight and seed filling percentage when compared to seed collected from the remaining four outlets operated with the same settings and bulk. Regarding seed filling, the outlets of B, C, D and E with C2 combination of machine settings recorded the highest filling percentage (100 %), whereas the seed collected from outlet A recorded the lowest value of 39.5 % (Table 1 & Figure 1). The percentage of germination recorded by seed collected from the outlet D with C2 was 97 percent. This value was 33, 6, 4, 1 and 6 percent higher than the seed collected from outlets A, B, C, E and ungraded bulk, respectively. The shoot length,

root length, dry matter production, vigour index I and vigour index II and field emergence percentage were

also followed the same trend as that of germination value recorded for all the five grades of seeds (Table 2, 3, 4 & Figure 1).

Table 1. Effect of specific gravity separation of seeds on seed recovery (%), 100 seed weight (g) and seed filling (%) of Annual moringa var. PKM1

Specific gravity grades	Seed recovery (%)				100 seed weight (g)				Seed filling (%)			
	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
A	2.5 (9.09)	5 (12.92)	8.3 (16.74)	5.27 (12.92)	23.09	21.87	24.31	23.09	57 (49.03)	40 (38.94)	64 (53.13)	57 (47.03)
B	13.7 (21.72)	15 (22.79)	22 (27.97)	16.90 (24.16)	23.62	26.37	24.89	24.96	79 (62.74)	100 (87.75)	82 (64.92)	79 (71.80)
C	35.9 (36.81)	32 (34.45)	24.4 (29.60)	30.77 (33.62)	25.15	28.17	25.58	26.30	86 (68.04)	100 (87.75)	87 (68.89)	86 (74.89)
D	32.2 (34.57)	35 (36.27)	33 (35.06)	33.40 (35.31)	26.51	32.78	28.15	29.15	99 (83.63)	100 (87.75)	99 (86.90)	99 (86.09)
E	15.7 (23.34)	13 (21.13)	12.3 (20.53)	13.67 (21.66)	26.45	29.57	26.28	27.43	89 (70.63)	100 (87.75)	89 (70.63)	89 (76.34)
F	-	-	-	-	27.82	27.82	27.82	27.82	98 (81.90)	98 (82.00)	98 (81.90)	98 (81.93)
Mean	20 (25.11)	20 (25.51)	20 (25.98)	20 (25.53)	25.44	27.76	26.17	26.46	84.67 (69.33)	89.58 (78.66)	86.50 (71.06)	84.67 (73.02)
	G	C		GXC	G	C		GXC	G	C		GXC
SEd	0.124	0.096		0.215	0.201	0.142		0.347	0.466	0.330		0.808
CD (P=0.05)	0.250	0.194		0.433	0.402	0.284		0.696	0.936	0.661		1.621

(Figure in parentheses indicate arc sine transformed values)

Combination	Machine setting adjustments			Seed grades		
	Horizontal height (cm)	Vertical height (cm)	Air blow rate (m3/hr)	A	D	Heavy weight
C1	0	1.0	3.5	B	E	Heavier weight
C2	0	1.5	4.0	C	F	Bulk
C3	0	2.0	4.5			

Among the biochemical parameters, the oil content was less in A, B, C, E and bulk seeds when compared to seed collected from outlet D of machine

operated with the settings of C2. The percentage decrease for A, B, C, E grades and bulk seeds compared with D grade were 43, 27, 18, 21 and 19.5 % respectively.

Table 2. Effect of specific gravity of seeds on seed germination (%) and speed of germination of Annual moringa var. PKM1

Specific gravity grades	Germination (%)				Speed of germination			
	C1	C2	C3	Mean	C1	C2	C3	Mean
A	74 (59.37)	64 (53.37)	77 (61.38)	71.67 (58.04)	2.14	1.87	2.02	2.01
B	80 (63.45)	91 (73.02)	79 (62.77)	83.33 (66.41)	2.41	2.41	2.30	2.37
C	84 (66.45)	93 (75.13)	85 (67.29)	87.33 (69.62)	2.82	2.94	2.74	2.83
D	89 (70.70)	97 (79.91)	92 (70.70)	92.67 (73.77)	3.20	3.24	3.09	3.18
E	87 (68.90)	96 (78.66)	88 (69.79)	90.33 (72.45)	3.06	3.21	2.87	3.05
F	91 (72.95)	91 (72.95)	91 (72.95)	91.00 (72.95)	3.15	3.15	3.15	3.15
Mean	84 (66.45)	88 (72.13)	85.33 (67.42)	86.06 (68.67)	2.66	2.80	2.69	2.77
	G	C		GXC	G	C		GXC
SEd	0.611	0.432		1.058	0.025	0.017		0.043
CD (P=0.05)	1.225	0.866		2.122	0.049	0.035		0.086

(Figure in parentheses indicate arc sine transformed values)

Combination	Machine setting adjustments			Seed grades		
	Horizontal height (cm)	Vertical height (cm)	Air blow rate (m3/hr)	A	D	Heavy weight
C1	0	1.0	3.5	B	E	Heavier weight
C2	0	1.5	4.0	C	F	Bulk
C3	0	2.0	4.5			

Similarly, the decreasing trend was recorded with reference to protein content of seed collected in the outlets of A, B, C, E and bulk seeds compared with

seeds collected from outlet D viz, 43, 26, 15, 0.4 and 10 % respectively.

Table 3. Effect of specific gravity of seeds on root length, shoot length (cm) and dry matter production (g/10 seedlings) of Annual moringa var. PKM1

Specific gravity grades	Root length (cm)				Shoot length (cm)				Dry matter production (g/10 seedlings)			
	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
A	4.13	4.80	4.19	4.37	14.81	14.76	15.07	14.88	0.42	0.47	0.43	0.44
B	4.30	5.30	4.30	4.63	15.18	16.25	15.69	15.71	0.43	0.50	0.44	0.46
C	4.45	6.21	4.68	5.11	15.82	16.36	16.45	16.21	0.45	0.51	0.46	0.47
D	4.71	7.69	5.69	6.03	16.76	18.16	17.26	17.39	0.49	0.57	0.51	0.52
E	4.65	7.34	5.00	5.66	16.45	17.43	16.85	16.91	0.47	0.54	0.47	0.49
F	5.18	5.32	5.18	5.23	17.02	16.29	17.02	16.78	0.52	0.52	0.52	0.52
Mean	4.56	6.11	4.84	5.17	16.00	16.54	16.39	16.31	0.46	0.52	0.47	0.48
	G	C		GXC	G	C		GXC	G	C		GXC
SEd	0.046	0.033		0.080	0.123	0.087		0.214	0.006	0.005		0.011
CD (P=0.05)	0.092	0.065		0.160	0.247	0.175		0.429	0.013	0.009		0.022

Combination	Machine setting adjustments				Seed grades				
	Horizontal height (cm)	Vertical height (cm)	Air blow rate (m3/hr)		A Lighter weight	D	Heavy weight		
C1		0	1.0		3.5		B Light weight	E	Heavier weight
C2		0	1.5		4.0		C Medium weight	F	Bulk
C3		0	2.0		4.5				

The carbohydrate content also followed the same trend as that of oil and protein content of seeds was collected from all five outlets (Table 5).

The data obtained in the present study showed that protein, carbohydrate and oil content decreased as the quality of seeds decreased.

Table 4. Effect of specific gravity of seeds on vigour Index I, vigour Index II and field emergence (%) of Annual moringa var. PKM1

Specific gravity grades	Vigour Index I				Vigour Index II				Field emergence (%)			
	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
A	1402	1252	1484	1379.33	30.70	30.08	32.98	31.25	62 (51.95)	51 (45.43)	69 (56.18)	60.67 (51.18)
B	1559	1961	1579	1699.67	34.22	45.50	34.57	38.10	65 (53.74)	71 (58.42)	70 (56.80)	68.67 (56.32)
C	1702	2098	1796	1865.33	37.80	48.36	38.69	41.62	70 (56.80)	76 (60.68)	72 (58.85)	72.67 (58.78)
D	1910	2507	2112	2176.33	43.85	55.29	46.93	48.69	78 (62.04)	88 (69.97)	86 (66.45)	84.00 (66.15)
E	1836	2378	1925	2046.33	40.91	51.84	41.34	44.70	77 (61.36)	84 (66.07)	79 (62.74)	80.00 (63.39)
F	2020	1966	2020	1966.00	47.31	46.41	47.31	46.41	85 (66.83)	85 (66.83)	85 (66.83)	85.00 (66.83)
Mean	1738.09	2027	1819.19	1855.50	39.13	46.25	40.30	41.79	72.83 (58.85)	76 (61.20)	76.33 (61.51)	75.17 (60.44)
	G	C		GXC	G	C		GXC	G	C		GXC
SEd	15.284	10.807		26.472	0.357	0.253		0.619	0.346	0.848		0.346
CD (P=0.05)	30.642	21.667		53.073	0.716	0.506		1.240	0.694	1.701		0.694

(Figure in parentheses indicate arc sine transformed values)

Combination	Machine setting adjustments				Seed grades				
	Horizontal height (cm)	Vertical height (cm)	Air blow rate (m3/hr)		A Lighter weight	D	Heavy weight		
C1		0	1.0		3.5		B Light weight	E	Heavier weight
C2		0	1.5		4.0		C Medium weight	F	Bulk
C3		0	2.0		4.5				

The observation on the filling percentages showed that, as the seed quality decreased, the filled seed percentage also decreased. The superiority

of the D grade seeds with reference seed filling, hundred seed weight, protein and oil contents, was recorded positively in the germination and seedling vigour.,

Table 5. Effect of specific gravity of seeds on oil content (%), protein content (%) and carbohydrates (%) of Annual moringa var. PKM1

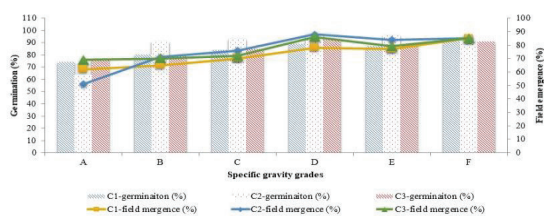
Specific gravity grades	Oil content (%)				Protein content (%)				Carbohydrates (%)			
	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
A	20.12 (26.65)	18.42 (25.49)	23.12 (28.74)	20.55 (26.96)	6.82 (15.12)	6.52 (14.78)	8.32 (16.76)	7.22 (15.55)	11.21 (19.56)	10.02 (18.45)	8.52 (16.97)	9.92 (18.33)
B	23.18 (28.78)	23.70 (29.12)	24.62 (29.75)	23.83 (29.22)	8.15 (16.59)	8.38 (16.82)	8.52 (16.97)	8.35 (16.79)	10.51 (18.91)	11.34 (19.67)	11.37 (19.71)	11.07 (19.43)
C	27.23 (31.46)	25.73 (30.48)	25.72 (30.47)	26.23 (30.80)	9.84 (18.27)	9.60 (18.05)	8.72 (17.17)	9.39 (17.83)	12.17 (20.42)	13.39 (21.45)	12.19 (20.43)	12.58 (20.77)
D	26.71 (31.12)	32.52 (34.76)	27.14 (31.40)	28.79 (32.42)	10.48 (18.88)	11.38 (19.71)	11.01 (19.38)	10.96 (19.32)	12.62 (20.81)	15.41 (23.10)	12.34 (20.57)	13.46 (21.49)
E	25.33 (30.22)	26.67 (31.09)	26.18 (30.78)	26.06 (30.70)	10.17 (18.60)	11.34 (19.67)	10.46 (18.87)	10.66 (19.04)	13.18 (21.28)	14.27 (22.18)	14.27 (22.19)	13.91 (21.88)
F	26.17 (30.77)	26.17 (30.77)	26.17 (30.77)	26.17 (30.77)	10.24 (18.65)	10.24 (18.65)	10.24 (18.65)	10.24 (18.65)	12.51 (20.70)	12.51 (20.70)	13.18 (21.28)	12.73 (20.89)
Mean	24.79 (29.83)	25.53 (30.27)	25.49 (30.32)	25.27 (30.14)	9.28 (17.69)	9.58 (17.95)	9.55 (17.97)	9.47 (17.87)	12.03 (20.28)	12.83 (20.93)	12.51 (20.70)	12.28 (20.64)
	G	C	GXC	G	C	GXC	G	C	GXC			
SEd	0.130	0.092	0.225	0.076	0.054	0.132	0.078	0.055	0.136			
CD (P=0.05)	0.261	0.184	0.451	0.152	0.108	0.264	0.157	0.111	0.272			

(Figure in parentheses indicate arc sine transformed values)

Combination	Machine setting adjustments			Seed grades			
	Horizontal height (cm)	Vertical height (cm)	Air blow rate (m3/hr)	A	Lighter weight	D	Heavy weight
C1	0	1.0	3.5	B	Light weight	E	Heavier weight
C2	0	1.5	4.0	C	Medium weight	F	Bulk
C3	0	2.0	4.5				

The presence of empty /ill filled seed, is reflected in the germination percentage of live seeds. Generally, annual moringa seeds are reported to have 5% of empty seeds.

Figure 1. Effect of specific gravity of seeds on seed germination (%) and field emergence of annual moringa var PKM1



The present-day moringa seed cost is around Rs.3000/kg, and every seed is important for regeneration purposes. Like that of moringa seeds, some other cultivated crops seed also have a similar kind of problem concerning seed quality up-gradation. Several authors have recorded their experience on the positive influence of upgrading the seed quality on the subsequent seed germination

and seedling vigour. Seed upgrading usually entails the removal of empty, immature, broken or insect-damaged seeds. After extraction and cleaning, seed lots should be further conditioned to upgrade the quality of the lots. Bonner and Switzer (1971) reported the significance of upgrading the seed quality of *Platanusoccidentalis* by the removal of empty seeds. Eucalyptus seeds were upgraded based on specific gravity by using water floatation or gravity separator to significantly increase the seed weight and germination (Dharmalingamet *al.*, 1973, Khan, 1976). Density grading of depulped neem drupes using water has produced better seedling production. Upgrading of *Casuarina equisetifolia* seeds with specific gravity separator significantly increased the seed weight, germination and biochemical constituents (Umarani and Vanangamudi 2002), Similar result of soybean seeds protein and oil content (Fehr 1967). Upgrading of Okra (Yogeshhet *al.*, 2013), Aggregatum Onion (Geetharaniet *al.*, 2008), Amaranths (Manikandan and Srimathi 2014), Lentil (Sinha *et al.*, 2009) and Onion cv. Arka Kalyan (Koteschi-Lamani and

Deshpande 2017) seeds on specific gravity separator significantly enhanced the seed germination and seedling vigour.

CONCLUSION

The optimization of a specific gravity separator machine for grading of moringa seeds revealed the optimum values for design and operation parameters such as horizontal height (cm), vertical height (cm), air blow rate (m³/hr) adjustments and deck oscillation (rpm). Optimum values of 0.0 cm, 1.5cm, 4.0 m³/hr and 450 rpm were obtained for horizontal height, vertical height, air blow rate adjustments and deck oscillation using bulk moringa seed lot, respectively. To assess the grading efficiency of the machine the following seed quality parameters viz., 100- seed weight, seed filling percentage and germination percentage were used as a check. The machine operated with above settings and seed collected from out let D recorded significantly higher values for seed filling percentage and germination percentage. Both the vertical height of the deck and air blow rate of the machine were found to affect significantly the grading process of the seed based on its size and weight.

ACKNOWLEDGMENTS

The authors thank the Dean, Agricultural Engineering College and Research Institute, Kumulur, Tiruchirappalli for providing the instrumentation facilities to carry out this experiment.

REFERENCES

- Abdul-Baki, A.A. and J.D. Anderson.1973. Vigour determination in soybean seed by multiple criteria. *Crop Sci.*, **13**: 630-632.
- Anderson, J.D. and A.A. Abdul-Baki. 1971. Glucose metabolism of embryos and endosperms from deteriorating barley and wheat seeds. *Plant Physiol.*, **48**: 270-272.
- Anwar, F., Latif, S., Ashraf, M. and A.H Gilani. 2007. *Moringa oleifera* a food plant with multiple medicinal uses. *Phytothera Res.*,**21**: 17-25.
- Aviara, N.A., Power, P.P. and T. Abbas. 2013. Moisture-dependent physical properties of *Moringa oleifera* seed relevant in bulk handling and mechanical processing. *Ind. Crop Prod.*, **42**: 96–104.
- Bansal, N.K. and S.K. Lohan. 2009. Design and development of an axial flow thresher for seed crops. *J. Agric. Eng.*,**46(1)**: 1-8.
- Bewley, J.D. and M. Black. 1983. Physiology and Biochemistry of Seeds in Relation to Germination. *Berlin, Springer-Verlag.*, 306.
- Bonner, F.T. and G.L. Switzer. 1971. *Upgrading Yellow Popular Seeds*. USDA Forest Research Note., 50-129.
- Datta, S.C. and K.K. Biswas. 1970. Germination-regulating mechanisms in aquatic angiosperms. I. *Ipomoea aquatica* Forsk. *Broteria.*, **39**:175-185.
- Dharmalingam, C., Daniel, S. D., Ramakrishna, V., Karivaratharaju T. V. and M. Thangaraj. 1973. Influence of seed separation and upgrading on germination in *Eucalyptus* hybrid seeds. *Madras Agric J.*, **60**: 1714-1718.
- Douglas, J. and J. Grabowski. 1997. A Comparison of Seed Cleaning Techniques for Improving Quality of Eastern Gama grass Seed, Jamie I. Whitten Plant Materials Centre, Coffeetown, MS., **13(7)**.
- Fadele, O.K. and A. K. Aremu. 2016. Design, construction and performance evaluation of a *Moringa oleifera* seed shelling machine. *Eng. Agric. Environ. Food.*, **9**: 250–256.
- Faizi, S., Siddiqui, B.S., Saleem, R., Shaheen, F., Aftab, K. and A.H. Gilani. 1998. Hypotensive constituents from the pods of *Moringa oleifera*. *Planta Med.*, **64**: 225–228.
- Faizi, S., Siddiqui, B.S., Saleem, R., Siddiqui, S., Aftab, K. and A.H. Gilani. 1995. Fully acetylated carbamate and hypotensive thiocarbamate glycosides from *Moringa oleifera*. *Phytochemistry.*, **38**: 957-963.
- Fakayode, O.A. and E. A. Ajav. 2016. Process optimization of mechanical oil expression from okra (*Okra oleifera*) seeds. *Ind. Crop Prod.*, **90**: 142–151.
- Fehr, W.R. 1967. Methods for evaluating protein and oil in soybeans and mass selection by seed size and specific gravity in soybean populations.
- Figueiredo, A.K., Rodriguez, L.M., Lindstrom, L.I., Riccobene, I.C. and S. M. Nolasco. 2013. Performance analysis of a de-hulling system for safflower grains. *Ind. Crop Prod.*, **43**:311–317.
- Figueiredo, A.K., Rodriguez, L.M., Riccobene, I.C. and S. M. Nolasco. 2014. Analysis of the performance of a dehulling system for confectionary sunflower seeds. *Food Nutr. Sci. Sci. Res.*, **5**: 541–548.
- Fuglie, L. 2001. The Miracle Tree, the Multiple Attributes of *Moringa* (Dakar, Senegal).
- Geetharani, P., Ponnuswamy, A.S., Manivannan, M.I., Rajangam, J. and S. Natarajan. 2008. Enhancing the sowing quality of seed by grading in onion (*Allium cepa* var *aggregatum*). *TAJH.*, **3**: 439-441.
- Gopalakrishnan., Lakshmi Priya., Kruthi Doriya. and S.K Devarai. 2016. *Moringa oleifera*, A review on nutritive importance and its medicinal application. *FSHW.*, **5(2)**: 49-56.
- Gupta, P. C. 1993. Seed vigour testing. Handbook of seed testing. New Delhi., **242-249**.
- Halloran, G.M. and W. J. Collins. 1974. Physiological predetermination of the order of hardseededness breakdown in subterranean clover (*Trifolium subterraneum* L.). *Ann. Bot.* **38**: 1039-1044.
- ISTA. 2014. International Seed Testing Association. Seed Vigour Testing. International Rules for Seed Testing, Zurich, Switzerland.
- Kang, H., Yi, S. and N. K. Chang. 1993. Maternal and paternal effects on seed yield components in cowpea (*Vigna unguiculata*). *Korean J. Bot.* **36**: 159-170.
- Khan, A. M. 1976. Report on FAO, DANIDA training course in Thailand on forest seed collection and

- handling. Pakistan Silviculture Division, Karachi, 32.
- Kotesli-Lamani and V.K Deshpande. 2017. Effect of different seed processing methods on seed recovery and seed quality of onion cv. *Arkakalyan*. *Int. J. Pure. app. Biosci.*,5:644-648.
- Kumar, C.S., Pradhan, R.C. and S. Mishra. 2016. Fabrication, performance evaluation and optimization of sal (*Shorea robusta*) seed decorticator. *J. Food Proc. Eng.* 1–10.
- Leone, Alessandro. 2016. Moringa oleifera seeds and oil: Characteristics and uses for human health. *Int. J. Mol. Sci.*,17: 2141.
- Lowry, O.H., Rosebrough, N.J. Farr,A.I.and R.J. Randall. 1951. Protein measurement with the Folin phenol reagent. *J Biol Chem.*, 193: 265-275.
- Maguire, J. D. 1962. Speed of Germination-Aid In Selection and Evaluation for Seedling Emergence And Vigour. *Crop sci.*, 2(2): 176-177.
- Manikandan, S. and P. Srimathi. 2014. Studies on post-harvest seed handling techniques on grain amaranth (*Amaranthus hypochondriacus L.*) cv. suvarna. *Current Biotica.*,8: 132-142.
- Natarajan, V., Venugopal, P.V. and T. Menon. 2003. Effect of Azadirachta Indica (neem) on the Growth Pattern of Dermatophytes. *Indian J Med Microbio.*,21(2): 98-101.
- Oliveira, J.T.A., Silveira,S.B.,Vasconcelos, I.M.,Cavada,B.S.and R.A. Moreira. 1999. Compositional and nutritional attributes of seeds from the multiple purpose tree *Moringa oleifera* Lam., *J. Sci. Food Agric.*,79: 815–820.
- Panse, V.G. and R.V Sukhatme. 1999. Statistical methods for Agricultural workers. Indian Council of Agricultural Research Publications, New Delhi.
- Rashid, U., Anwar, F., Ashraf, M., Saleem, M. and S. Yusup. 2011. Application of response surface methodology for optimizing transesterification of Okra oleifera oil: biodieselproduction. *Energy Convers. Manage.*,52: 3034–3042.
- Saini, R.K., Iyakkannu,S.and S.K. Young-Soo. 2016. Phytochemicals of *Moringa oleifera*: a review of their nutritional, therapeutic and industrial significance. *Biotech.*,6(2): 203.
- Santos, A.F.S., Paiva,P.M.G., Teixeira, J.A.C., Brito, A.G.,CoelhoL.C.B.B.and R. Nogueira. 2012. Coagulant properties of Moringa oleifera protein preparations: application to humic acid removal. *Environ. Technol.*,33: 69-75.
- Singh R., Indramani and A. Rai. 2010. Development of performance index for onion seed extractor. *J. Agric. Eng.*, 47(3): 8-14.
- Sinha, J.P., Dhaliwal,J.S.and S.N Sinha. 2009. Effect of machine parameters on threshing quality for seed crop in chick pea. *J. Agric. Eng.*, 46(4), 11-16.
- Sinha, J.P., Vishwakarma,M.Kand S.X. Sinha. 2009. Quality improvement in lentil (*Lens culinaris medic*) seed through mechanical seed processing. *J Res.*, 8:7-17.
- Sivasubramanian, K. 1996. Studies on certain aspects of seed quality in Moringa (*Moringa PterygospermaGearth*) Pkm-1.Ph.D. (Ag) Thesis. Tamil Nadu Agricultural University, Coimbatore.
- Susko, D.J. 2006. Effect of ovule position on patterns of seed maturation and abortion in *Robiniapseudoacacia*(Fabaceae). *Can. J. Bot.*,84: 1259-1265.
- Taylor, K.A. 1995. A modification of the phenol/ sulfuric acid assay for total carbohydrates giving more comparable absorbance. *Applbiochem biotech.*,53(3): 207-214.
- Umarani, R. and K. Vanangamudi. 2002. The effect of specific gravity separation on germination and biochemical potential of *Casuarina equisetifolia* seeds. *J. Trop. For. Sci.*, 14: 207-212.
- Van-Staden, J. and N.A.C. Brown.1997. Studies on the germination of South African proteaceae a review. *Seed Sci. and Tech.*, 5: 633-643.
- Verma S.R. and H. Singh.1988. Development of an axial flow vegetable seed extracting machine. *J. Agric. Eng.*, 25(1): 98-104.
- Yogeesha, H.S., Kashinath, B.L.,Bhanuprakash,k.and L.B. Naik. 2013. Seed quality improvement in okra through specific gravity separation. *J. Hortl. Sci.*, 8: 70-73.