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A Correlation Study of pre-sowing Treatments, Sowing Positions and Age of Stones after Extraction from Fruit on Germination of Mango

U R RESHMA* AND S SIMI

ABSTRACT

The present study was undertaken to assess the correlation relationship between various pre-soaking treatments, sowing positions and age of stone on germination and vigour of mango seedlings. Mango stones of different age groups viz., freshly extracted stones, 10 and 20 days after extraction of pulp were soaked in aqueous solutions of GA_3 (100 and 200 ppm), KNO_3 (1 and 2 ppm), cow dung slurry, water and control (without treatments) for 24 hours and were sown in flat and stalk end up method. The correlation coefficients indicate the presence of inherent association between various characters under study. The study revealed that the seedling vigour index –I had very high positive and very dependable relationship with germination percentage (r=0.988**) and seedling length (r=0.974**) whereas seedling vigour index-II had very high positive, significant correlation and very dependable relationship with seedling length (0.931**) in case of stalk end up method over the flat method of sowing.

KEYWORDS

Age, correlation, germination, presowing treatments, sowing positions

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INTRODUCTION

In the past two decades, India has witnessed an increase in the area under mango on account of demand for fresh fruits in the domestic as well as international market. However, limited availability of genuine planting material is a major bottleneck in the expansion of area under mango (Kacha *et al*, 2021). As mango is a highly cross pollinated crop, there is an enormous variation in the seedlings raised even from the fruits of the same tree. When raised by seeds, mango plants are not true to type and lose many of their unique characteristics. Vegetative propagation thus became a necessity in mango to preserve and perpetuate the characteristics of each cultivar. Mango is commercially propagated by grafting in different parts of the country. For successful graft union, rootstocks should be healthy, strong and vigorous (Patel *et al*, 2017).

Owing to recalcitrant nature, mango stones are characterized by low viability. There is only about 12-50 per cent germination when sown within a month after extraction (Gill and Sandhu, 1985). Usually the mango stones are available during the drier part of the year (April- May). As a result of which, seedling vigour and survival percentage is very low. On an average mango stones begin to germinate in about 12 days after sowing, but may take more than a month to complete germination. Mango seeds have a stony endocarp which inhibits germination. Moreover, Seeds need the right environmental conditions and a favourable internal environment to germinate. There are several factors other than hard seed coat which affects the seed germination in mango viz., size and weight of stones, depth of sowing, soil media and environmental factors such as oxygen, water, temperature, soil type., etc. Besides, the occurrence of true vivipary was observed in some mango varieties though is of unusual occurrence**.** This Viviparous fruits are fully matured and relatively smaller and characterized with low pulp stone ratio and high moisture content. It may be presumed that the occurrence of true vivipary in mango may be due to recalcitrant nature of seed and increase in relative humidity during fruit maturity. This phenomenon also adversely affects the germination. Stone germination in mango is a slow and sporadic process and consequently the seedlings take more time to attain graftable size (Patel *et al*, 2017).

For successful graft union, it is imperative to have healthy, strong and actively growing rootstocks. To achieve a perceptible difference in stone germination and rapid seedling emergence, sowing positions (seed orientation), age of stones and pre-sowing treatments are need to be taken into consideration.Several workers have reported that pre-sowing treatments with various chemicals such as GA_3, KNO_3, thiourea etc. as well as organic formulations for 12-36 hours has been proved to be effective for enabling the fastest, higher seedling vigour as well as seedlings with low mortality rate. Pre sowing treatments also protect seeds from various biotic and abiotic stresses during critical phases of seedling growth and establishment (Muralidhara *et al*, 2015).

On the other hand, age of stone after extraction from the fruit as well as the seed orientation on seed bed also can make significantly higher differences in germination and subsequent growth of seedlings. Age of stone is critical factor need to be taken into consideration for seed propagation, as the viability and quality of recalcitrant seeds directly depend upon the seed moisture content (Donald, 2007). Moreover, sowing of

[1] Deptt. of Fruit Science, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala -695522, India
*Corresponding author email: reshmaraveendran566@gmail.com

seeds at proper position and depth is one of the most important nursery operations as it affects the germination and subsequent growth of the plant (Garner and Chaudhri, 1976).
With these facts in view, the present investigation was undertaken to appraise the correlation among pre-sowing treatments, sowing positions and age of stones after extraction on germination behaviour of mango.

MATERIALS AND METHODS

The present study was carried out during 2018 – 2019 at the College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The experiment was laid out in Factorial Completely Randomized Block Design with 42 treatments. The treatments comprise of different combinations of 2 sowing positions (flat and stalk end up), 3 different age group of stones after extraction from fruit (freshly extracted stone, 10 days after extraction, and 20 days after extraction) and 7 pre-sowing treatments (GA_3- 100, GA_3 – 200 ppm, KNO_3 -1 ppm, KNO_3 - 2 ppm, cow dung slurry, water and control). Fruits of `Kotookonam Varikka' variety of mango were selected for the study. The average stone weight of each age groups were recorded accordingly. The average stone weight was 29.85 g for freshly harvested, 28.02 g for stones which were sown 10 days after extraction and 24.63 g for the stones which were sown 20 days after extraction respectively. After extraction, the stones were washed thoroughly and were soaked in various pre-soaking solutions for 24 hours prior to sowing. The pre-treated mango stones of different age groups were sown at proper spacing in stalk end up and flat positions in the seed bed. The depth of the seedling-bed to sow mango seeds were 25 cm of soil substrate and seeds were sown at 15 cm of depth. The germination of stones started 15 days after sowing and continued upto 55 days. Total of 25 stones were sown in each treatment. Observations were recorded daily for germination parameters, whereas the vegetative parameters like seedling length, dry weight and seedling vigour index I & II were recorded at 4 months after sowing.
The germination percentage (Patel *et al*, 2016) was calculated as follows:

$$Germination\ percentage = \frac{Number\ of\ stones\ germinated}{Total\ number\ of\ stones\ sown} \times 100$$

The rate of germination (Bewley and Black, 1982) was calculated as:

$$Rate\ of\ germination = \frac{Germination\ percentage}{Number\ of\ days\ taken\ for\ germination}$$

Vigour index - I (growth basis) and Vigour index - II (weight basis) were calculated using the formula given by Kumar *et al* (2007) as follows;
Vigour Index –I = germination percentage (%) x [shoot length (cm) + root length (cm)
Vigour Index – II = germination percentage (%) x dry weight of seedling (g)
The experimental data recorded was subjected to statistical analysis as per the method suggested by Panse and Sukhatme (1967). The treatment means were separated using F test values at 5% level of significance. The correlation studies were done by Karl Pearson's method.

RESULTS AND DISCUSSION

Effect of sowing positions on germination and vigour of mango seedlings

The perusal of data presented in table 1 clearly indicated that the stalk end up method of sowing was found superior with respect to earliness in germination (22.95 days) and the least number of days for 50 percentage germination (31.75 days), the highest germination (60.85 %), germination rate (0.47), seedling length (34.63 cm), dry weight (9.77 g), seedling vigour I (2176.50) and II (603.27) over flat method of sowing (Table 1).
The amount of energy required to accomplish germination varies according to genotype and seed orientation on seed bed because of the quantity of stored nutrients, especially endosperm and positioning of micropyle, respectively in cashew (Hammed *et al*, 2014). Naturally, the radicle has a positive geotropism whereas the shoot of the germinating seed has a negative geotropism. Supporting the upcoming response of the seedling to the stimulus (gravity) is highly correlated with the orientation of micropyle. The tip of the root bends downward if the seeds oriented vertically upward with respect to micropyle. The roots of seed sown by mycropyle in vertically upright position need to curve over the seed itself in order to grow in downward (normal) direction in tree species (Coutts, 1989).
Mango stones with stalk-end up position of sowing places the micropyle in the most suitable position, i.e., pointing downward, the roots of the seed grew easily and directly downward (does not require bending), which requires less energy for germination and radicle emerge from the embryo (Vijaya and Satyanarayana, 2004). Hence it resulted with highest germination percentage and earliness in germination in Stalk end up method.
The seedlings whose roots grow properly without any curvature will establish well for its function and growth, which can ultimately improve the performance. Hence, stalk end up method resulted in the highest seedling length and dry weight which ultimately resulted in better seedling vigour indices, both on growth and weight basis over the flat method of sowing.
The improper orientation of seeds could impoverish the emerging embryo for needed quantum of oxygen which could lead to the synthesis of higher amount of ethanol and pyruvate in the plant system and finally leads to the death of the emerging embryo (Bewley, 1997). This might be the probable reason for reduced germination and poor quantitative plant vigour in seeds sown in flat method.

Effect of age of stones after extraction from the fruit

It is evident from the Table 2 that the least number of days for initiation of germination (22.95 days) and 50 per cent germi-

Table 1: Effect of sowing positions (seed orientation) on germination and vigour of mango seedlings

Sowing positions	Days taken for initiation of germination	Days taken for 50 % germination	Germination (%)	Rate of germination	Seedling length (cm)	Dry weight of seedling (g)	Seedling vigour index -I (Growth basis)	Seedling vigour index- II (Weight basis)
Flat	29.15	40.91	40.95	0.26	28.12	7.23	1192.08	305.72
Stalk end up	22.95	31.75	60.85	0.47	34.63	9.77	2176.50	603.27
SE(m)	0.05	0.17	0.69	0.001	0.10	0.04	26.48	12.49
CD $_{0.05}$	0.13	0.47	1.94	0.004	0.28	0.12	74.48	35.13

nation (31.29), the highest germination (59.84 %), rate of germination (0.47), seedling length (36.60 cm), dry weight (9.85), seedling vigour indices on growth basis (2241.88) and weight basis (594.08) were the best for the freshly harvested stones than stones sown at 10 days and 20 days after extraction from fruit.

The germination ability of a seed was directly related to its moisture content as well as the rate at which seeds lose its moisture thereby affecting the viability in Calamus species (Patil and Krishna, 2016). The reduction in viability and vigour were proportional to increased leaching of metabolites from seeds and decreased dehydrogenated activity of seeds. The leaching of metabolites increases with decreased seed moisture content during storage.

The freshly extracted seeds had considerable amount of post imbibition hydrolysis of non-reducing sugars and DNA-P (DNA polymerase) which resulting in initiation of protein synthesis, little or none could be observed as age advances in mango (Chandra, 1980). The higher expression of DNA-P in imbibed seeds enhancing the protection against DNA damage and allows successful germination of rice seeds (Sihi *et al*, 2015). Germination became progressively slower as the age advanced.

Effect of pre-sowing treatments on germination and vigour of mango seedlings

It is evident from table 3 that the pre-sowing treatments had a significant effect on growth and vigour of mango seedlings. The stones treated with 200 ppm GA_3 recorded the least number of days for initiation of germination (22.62 days), for 50 per cent germination (31.78 days), the highest germination percentage (62.59 %) and rate of germination (0.48), significantly higher vigour index- I (2310.02) and vigour index- II (657.09) on growth and weight basis. The highest seedling length (35.70 cm) and dry weight (10.39 g) of the mango seedlings were observed in 100 ppm GA_3. The poorest germination, vigour and growth characteristics of mango seedlings were observed in control (without any treatment).

The earliest stone germination in GA_3 might be due to the increased concentration of endogenous auxin content due to the GA_3 application as the GA_3 is the vital component of auxin signalling pathway (Ross et al., 2002). In aonla, the increased level of auxin and enhanced enzymatic activities along with the repression of inhibitors might be the probable reasons for faster germination. GA_3 might have also triggered the starch hydrolysis and their translocation to the growing seedlings thereby inducing early germination (Rajamanickam *et al*, 2004).

The presence of GA_3 inside the seed which stimulates the imbibition process on subsequent seed germination. Presoaking treatment of GA_3 might have affected directly and altered various enzymatic reactions, synthesis of proteins and conversion of starch into sugars involved in the process of germination (Paleg, 1960). On the other hand, GA_3 also induces the denovo synthesis of proteolytic enzymes like ribonuclease and α-Amylase. The enzyme α-amylase and accompanying hydrolytic enzyme(s) successively hydrolyse the starch in endosperm thereby providing essential sugars for growth initiation processes and also liberate chemical energy which is utilized for RNA synthesis, activation of embryo as well as the suppression of inhibition which in turn resulted in higher germination (Copeland and Mcdonald, 1995). GA_3 treatment also have an ability to overrule the thermo-dormancy, photo dormancy, dormancy imposed by incomplete development of embryo, presence of various germination inhibitors as well as mechanical barriers in peach (Diaz and Martin, 1971).

In general, the regulation of growth by gibberellins and potassium nitrate relates virtually to its stem elongation properties, especially due to the enhancement of metabolites responsible for cell division and enlargement of cell. These chemicals act exclusively on stem elongation by loosening the cell wall, increasing the concentration of solutes by increasing the extensibility of cell wall, stimulating cell wall synthesis, reducing the cell wall rigidity and by increasing cell division leading to more efficient growth. The indirect effect caused by these chemicals on stem elongation is by increasing the IAA synthesis that leads to more vegetative growth (Leopold and Krieddemann, 1983).

Increase in dry weight of seedlings by GA_3 application might be due to the improved mobilization of the nutrients, which promotes the plant growth and development in better way. In khirnee the GA_3 treatment might have resulted into higher production of photosynthates and their translocation through phloem tissue to the root zone might have led to increase in the production of lateral roots thereby increasing the root

Table 2: Effect of age of stones after extraction from the fruit on germination and vigour of mango seedlings

Age of stones after extraction from the fruit	Days taken for initiation of germination	Days taken for 50 % germination	Germination (%)	Rate of germination	Seedling length (cm)	Dry weight of seedling (g)	Seedling vigour index -I (Growth basis)	Seedling vigour index-II (Weight basis)
Freshly extracted stone	18.56	31.29	59.84	0.47	36.60	9.85	2241.88	594.08
10 days after extraction	24.56	36.50	52.38	0.36	31.57	8.32	1714.50	458.53
20 days after extraction	35.03	41.20	40.48	0.28	25.95	7.33	1096.50	310.87
SE(m)	0.06	0.20	0.85	0.002	0.12	0.05	32.43	15.30
CD $_{0.05}$	0.16	0.57	2.38	0.005	0.34	0.15	91.22	43.03

length (Vachhani *et al*, 2014). The exogenous application of GA_3 also triggered the activity of gluconeogenic enzyme during the early stages of seed germination and this could be a probable reason for improved vigour characteristics which directly reflected on more production of lateral roots as well as increased root length, thereby improved the shoot growth in tamarind (Vasantha *et al*, 2014). This might have resulted in increased total dry weight of the seedling. In pea seedlings the cumulative effect of better root and shoot growth as well as more production of lateral roots have led to overall assimilation and redistribution of photosynthates within the plant system, thereby promoting the better growth and development (Brian and Hemming, 1955).

The better results with respect to vigour indices might be due to the cumulative effect of higher germination percentage, shoot length, root length and seedling dry weight under GA_3 treatment.

Interaction effect of sowing positions, age of stones after extraction from the fruit and pre-sowing treatments on germination and vigour of mango seedlings

Interaction effects (Table 4) also indicated that the sowing of freshly extracted stones by stalk end up method after treatment with 200 ppm GA_3 for 24 hours resulted in significantly higher germination rate (0.74) and minimum days for initiation of germination (13.00 days). Whereas the highest seedling length (44.43 cm) and dry weight (14.72 g) was recorded in stalk end up method after treatment with 100 ppm GA_3 for 24 hours. Sowing of stones 20 days after extraction from the fruit by flat method without any pre-sowing treatments resulted in poor germination as well as vigour of mango seedlings.

Correlation analysis of pre-sowing treatments and age of the stones after extraction on germination and vigour of mango seedlings by flat method of sowing

The results obtained from the present investigation are summarized below: The close perusal of correlation analysis (Table 5) revealed that, there was a significant, very highly positive correlation and very dependable relationship between number of days taken for initiation of germination and days taken for 50 % of germination (r=0.932**). The germination percentage had strong negative linear relationship and non-significant correlation with number of days taken for initiation of germination (r= -0.803) and number of days taken for 50 % germination (r= -0.901).

The germination rate had strong negative and non-significant correlation with number of days taken for initiation of germination (r= -0.884) and number of days taken for 50 % germination (r= -0.901) but had a highly positive correlation (r=837**) and marked relationship with germination percentage.

The seedling length had a non-significant and strong negative linear relationship between number of days taken for initiation of germination (r= -0.920) and number of days taken for 50 % germination (r= -0.918) but found highly positive correlation along with marked relationship between germination percentage (r=0.798**) and germination rate (0.848**).

The dry weight of seedling had non-significant and strong negative correlation with number of days taken for initiation of germination (r= -0.802) and number of days taken for 50 % germination (r= -0.905) but found positive correlation and marked linear relationship between germination percentage (r=0.785**) and germination rate (0.796**). The dry weight of seedling correlated very strongly and showed a very dependable relationship with seedling length (0.910**).

Seedling Vigour Index-I (SVI-I) had strong negative and non-significant linear relationship between number of days taken for initiation of germination (r= -0.903) and number of days taken for 50 % germination (r= -0.960). SVI-I had very highly positive, significant and very dependable relationship with germination percentage (r= 0.958**) and seedling length (r= 0.937**). SVI-I had highly positive (significant) and marked relationship between germination rate (0.889**) and dry weight of the seedling (0.887**).

Seedling Vigour Index-II (SVI-II) had strong negative and non-significant linear correlation with number of days taken for 50 % germination (r= -0.953) and days taken for initiation of germination (r= -0.849). SVI-II had very highly positive, significant correlation and very dependable relationship with germination percentage (r= 0.965**), dry weight of seedling (r=0.920**) and SVI-I (0.982**). SVI-II had highly positive and

Table 3: Effect of pre-sowing treatments on germination and vigour of mango seedlings

Pre-sowing treatments	Days taken for initiation of germination	Days taken for 50 % germination	Germination (%)	Rate of germination	Seedling length (cm)	Dry weight of seedling (g)	Seedling vigour index -I (Growth basis)	Seedling vigour index- II (Weight basis)
GA_3 - 100 ppm	23.89	33.94	55.19	0.43	35.70	10.39	1984.48	546.23
GA_3 - 200 ppm	22.62	31.78	62.59	0.48	34.70	10.01	2310.02	657.09
KNO_3 - 1 ppm	24.49	34.17	52.96	0.42	33.26	9.22	1834.42	513.80
KNO_3 - 2 ppm	25.69	35.56	50.00	0.36	32.27	8.59	1694.86	454.53
Cow dung slurry	25.78	35.78	53.19	0.35	30.05	7.77	1740.60	444.77
Water	28.84	40.11	42.96	0.31	27.82	7.12	1248.63	316.76
Control (no treatment)	31.01	42.94	37.41	0.25	25.83	6.39	977.03	248.33
SE(m)	0.09	0.31	1.29	0.003	0.19	0.08	49.54	23.37
$CD_{0.05}$	0.24	0.87	3.63	0.008	0.53	0.22	139.34	65.73

significant marked linear relationship with germination rate (0.0.867**) and seedling length (0.891**).

Correlation analysis of pre-sowing treatments and age of the stones after extraction on germination and vigour of mango seedlings by stalk end up method of sowing

It is evident from Table 6 that there was a significant, highly positive correlation and marked relationship between days taken for initiation of germination and days taken for 50 % germination (r=0.837**). The germination percentage showed a strong negative and non-significant linear correlation with number of days taken for initiation of germination (r= -0.893) and number of days taken for 50 % germination (r= -0.889). The germination rate had moderate negative and non-significant linear relationship with number of days taken for initiation of germination (r= -0.517) and non-significant, strong negative relationship with number of days taken for 50 % germination (r= -0.766) but had a moderate positive, significant correlation (r=668*) and substantial relationship with germination percentage ($p \leq 0.05$).

Table 4: Interaction effect ofsowing positions, age of stones after extraction from the fruit and pre-sowing treatments on germination and vigour of mango seedlings

Sl. no.	Treatments	Days taken for initiation of germination	Days taken for 50 % germination	Germination (%)	Rate of germination	Seedling length (cm)	Dry weight of seedling (g)	Seedling vigour index -I (Growth basis)	Seedling vigour index- II (Weight basis)
1	$S_1A_1T_1$	19.13	31.33	53.33	0.51	37.26	9.60	1918.80	511.44
2	$S_1A_1T_2$	17.73	30.33	62.22	0.58	36.02	9.16	2319.70	569.87
3	$S_1A_1T_3$	18.33	31.67	51.11	0.51	34.83	8.65	1781.80	442.24
4	$S_1A_1T_4$	21.00	33.67	46.67	0.40	34.42	8.36	1611.42	390.17
5	$S_1A_1T_5$	22.20	33.33	53.33	0.41	31.55	7.75	1680.84	412.84
6	$S_1A_1T_6$	23.73	38.34	40.00	0.26	29.50	7.35	1180.86	293.35

Continued on next page

Table 4 continued

7	$S_1A_1T_7$	25.73	42.33	35.55	0.21	27.71	6.49	985.58	231.59
8	$S_1A_2T_1$	26.00	37.34	51.11	0.24	32.31	8.00	1348.99	351.10
9	$S_1A_2T_2$	24.00	36.33	42.22	0.25	31.92	8.32	1650.36	408.90
10	$S_1A_2T_3$	26.53	41.33	40.00	0.24	30.68	7.56	1230.04	302.38
11	$S_1A_2T_4$	27.67	41.67	35.55	0.26	30.30	7.23	1074.99	257.56
12	$S_1A_2T_5$	26.87	39.33	44.45	0.26	27.04	6.78	1203.30	300.97
13	$S_1A_2T_6$	31.60	45.34	33.33	0.21	25.31	6.39	816.15	211.73
14	$S_1A_2T_7$	33.27	47.66	31.11	0.15	23.01	5.75	715.64	178.88
15	$S_1A_3T_1$	36.80	44.67	37.38	0.14	24.67	7.16	909.52	281.37
16	$S_1A_3T_2$	35.47	41.00	44.45	0.21	24.08	7.45	1096.77	318.91
17	$S_1A_3T_3$	37.40	44.33	35.55	0.16	23.77	6.81	845.01	242.81
18	$S_1A_3T_4$	37.94	45.34	31.11	0.14	23.14	6.40	719.48	199.01
19	$S_1A_3T_5$	37.20	47.00	37.78	0.14	23.05	6.32	871.44	238.70
20	$S_1A_3T_6$	40.27	51.00	28.89	0.12	21.12	5.58	612.77	161.51
21	$S_1A_3T_7$	43.20	55.67	24.45	0.11	18.81	4.71	460.21	114.83
22	$S_2A_1T_1$	13.53	26.34	73.33	0.66	44.43	14.72	3199.11	740.22
23	$S_2A_1T_2$	13.00	23.00	82.22	0.74	43.58	14.25	3631.36	1172.35
24	$S_2A_1T_3$	14.67	24.33	73.33	0.60	42.85	13.00	3078.84	954.35
25	$S_2A_1T_4$	16.40	27.34	68.89	0.42	42.89	12.21	2906.15	842.05
26	$S_2A_1T_5$	16.07	28.66	75.56	0.42	38.92	10.18	3031.21	770.52
27	$S_2A_1T_6$	18.33	32.00	64.45	0.45	36.20	8.46	2333.45	545.04
28	$S_2A_1T_7$	19.93	35.33	57.78	0.33	34.06	7.63	1727.12	441.08
29	$S_2A_2T_1$	19.53	30.00	66.67	0.56	40.55	12.13	2525.93	807.47
30	$S_2A_2T_2$	18.53	28.33	75.55	0.60	37.85	11.87	3063.35	895.88
31	$S_2A_2T_3$	20.87	30.00	68.89	0.58	36.55	10.04	2521.19	690.45
32	$S_2A_2T_4$	21.27	30.33	73.33	0.50	35.10	9.16	2576.93	673.64
33	$S_2A_2T_5$	20.40	31.34	71.11	0.45	33.09	8.25	2352.69	587.25
34	$S_2A_2T_6$	22.47	35.00	55.55	0.41	30.13	7.90	1674.15	438.09
35	$S_2A_2T_7$	24.73	37.00	44.45	0.33	28.18	7.09	1249.24	315.19
36	$S_2A_3T_1$	28.33	34.00	57.78	0.42	34.96	10.13	2004.51	576.62
37	$S_2A_3T_2$	27.00	31.67	60.00	0.44	34.73	9.61	2098.58	585.76
38	$S_2A_3T_3$	29.13	33.33	48.89	0.42	31.67	9.24	1549.62	450.55
39	$S_2A_3T_4$	29.87	35.00	44.45	0.41	28.78	8.19	1280.20	364.70
40	$S_2A_3T_5$	32.00	35.00	48.89	0.41	26.65	7.34	1304.12	358.29
41	$S_2A_3T_6$	36.67	39.00	35.55	0.40	24.70	7.05	874.36	250.80
42	$S_2A_3T_7$	39.20	39.67	31.11	0.34	23.24	6.68	724.35	208.39
SE(m)		0.21	N.S	N.S	0.007	0.46	0.20	N.S	N.S
$CD_{0.05}$		0.60	N.S	N.S	0.019	1.30	0.54	N.S	N.S

S_1: Flat S_2: Stalk end up A_1: Freshly extracted stone A_2: 10 days after extraction A_3: 20 days after extraction
T_1: GA_3- 100 ppm T_2: GA_3 - 200 ppm T_3: KNO_3- 1 ppm T_4: KNO_3 -2 ppm T_5: Cow dung slurry
T_6: Water T_7: Control (No treatment)

Table 5: Correlation analysis of pre-sowing treatments and age of the stones after extraction on germination and vigour of mango seedlings by flat method of sowing

	Days taken forinitiation of germination	Days takenfor50 % germination	Germination (%)	Germination rate	Seedling length (cm)	Dry weightof seedling (g)	Seedling vigour index –I (Growth basis)	Seedling vigour index- II (Weight basis)
Days taken for initiation of germination	1							
Days taken for 50 % germination	0.932**	1						
Germination percentage	-0.803	-0.901	1					
Germination rate	-0.884	-0.901	0.837**	1				
Seedling length	-0.920	-0.918	0.798**	0.848**	1			
Dry weight of Seedling	-0.802	-0.905	0.785**	0.796**	0.910**	1		
Seedling vigour index –I	-0.903	-0.960	0.958**	0.889**	0.937**	0.887**	1	
Seedling vigour index- II	-0.849	-0.953	0.965**	0.867**	0.891**	0.920**	0.982**	1

* Correlation is significant at the 0.05 level of probability;
** Correlation is significant at the 0.01 level of probability; others are non-significant.

The seedling length had non-significant and strong negative linear relationship between number of days taken for initiation of germination (r= -0.950) and number of days taken for 50 % germination (r= -0.939) but also found very high and very dependable linear relationship with germination percentage (r=0.928**) and moderate correlation and substantial linear relationship with germination rate (0.705*).

The dry weight of seedling had non-significant and weak negative linear relationship with number of days taken for initiation of germination (r= -0.456) and non-significant as well as strong negative linear correlation with number of days taken for 50 % germination (r= -0.787). The dry weight of seedling had moderate positive non-significant correlation and substantial linear relationship with germination percentage (r=0.570) and seedling length (0.660*) but showed highly significant positive correlation and substantial relationship with germination rate (0.793**).

Seedling Vigour Index-I (SVI-I) had very strong negative and non-significant correlation with number of days taken for 50 % germination (r= -0.925) and number of days taken for initiation of germination (r= -0.933). SVI-I had very highly positive and significant correlation as well as very dependable relationship with germination percentage (r= 0.988**) and seedling length (r=0.974**). SVI-I had moderate significant correlation and substantial relationship with germination rate (0.695*) but non-significant moderate correlation and substantial relationship with dry weight of the seedling (0.618).

Seedling Vigour Index-II (SVI-II) had strong negative and non-significant correlation with number of days taken for 50 % germination (r= -0.952) and days taken for initiation of germination (r= -0.823). SVI-II had very highly positive, significant correlation and very dependable relationship with germination percentage (r= 0.941**), seedling length (0.931**) and SVI-I (0.953**). SVI-II had a highly positive correlation and marked linear relationship with germination rate (0.0.799**) and dry weight of seedling (r=0.814**).

CONCLUSION

Germination became progressively slower as the age advanced. The micropyle positioning while sowing has direct implications on germination as well as seedling quality as it determines the uniformity, speed and rate of germination. Hence best results were obtained by sowing of mango stones by stalk end up method (micropyle pointing downward). The pre-soaking treatment with GA_3 treatment 24 hours prior to sowing resulted in the earliest germination, the highest

Table 6: Correlation analysis of pre-sowing treatments and age of the stones after extraction on germination and vigour of mango seedlings by stalk end up method of sowing

	Days taken for initiation of germination	Days takenfor 50 % germination	Germination (%)	Germination rate	Seedling length (cm)	Dry weightof seedling (g)	Seedling vigour index –I (Growth basis)	Seedling vigour index--II (Weight basis)
Days taken for initiation of germination	1							
Days taken for 50 % germination	0.837**	1						
Germination percentage	-0.893	-0.889	1					
Germination rate	-0.517	-0.766	0.668*	1				
Seedling length	-0.950	-0.939	0.928**	0.705*	1			
Dry weight of Seedling	-0.456	-0.787	0.570	0.793**	0.660*	1		
Seedling vigour index –I	-0.933	-0.925	0.988**	0.695*	0.974**	0.618	1	
Seedling vigour index- II	-0.823	-0.952	0.941**	0.799**	0.931**	0.814**	0.953**	1

* Correlation is significant at 0.05 level of probability;
** Correlation is significant at 0.01 level of probability; others are non-significant

germination and seedling vigour with lower mortality rate. Hence the cumulative effect of viable and physiologically more active freshly harvested stones which were pre-treated with GA_3 and sown in stalk end up position resulted in better germination and vigour of mango seedlings. Significantly superior and highly positive correlations between vigour indices and germination characteristics were observed in stalk end up method over flat method of sowing as influenced by different age groups of stone and various pre-sowing treatments in mango.

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