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Clay Mineral Application and its Effect on Establishment and Growth of Custard Apple in Alfisols of Semi-Arid Environment

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ABSTRACT: A study was conducted to assess the effects of clay mineral application @ 0, 1.2, 2.4 and 4.8 kg/pit on different morphological and physiological parameters in custard apple under Alfisols in semi-arid conditions. There was no significant effect of clay mineral on height and spread in both North-South and East-West directions of custard apple trees up to 300 days after planting (DAP); while it had a significant effect at 439 and 704 DAP for height and number of branches; and canopy spread. A similar impact was noticed in case of stomatal conductance and relative water content and canopy temperature at 158 DAP. Height was significantly related with number of branches (439 and 704 DAP); north-south and east-west spread (704 DAP); and girth (704 DAP). Number of branches had a significant relation with north-south and east-west spread (704 DAP); girth (704 DAP). Significant relations of east-west and north-south spread (704 DAP) with girth; stomatal conductance and relative water content at 158 DAP were observed. Height was significantly related with number of branches, while rainfall was related with height and number of branches. Based on regression analysis, the influence of clay minerals on different parameters was assessed. Application of 4.8 kg/pit of clay mineral was found to be efficient in improving height and number of branches of custard apple under Alfisols in semi-arid conditions.

Key words: Custard apple, microsite improvement, clay mineral, Alfisol

Horticultural production in drylands has lesser risk unlike annual crops and would provide stability in income and improve standard of living of rainfed farmers. Fruit crops are perennial, deep rooted and possess xerophytic characters enabling them to tolerate climatic aberrations and stress conditions. Production of fruits and vegetables in drylands would make nutritive food available to the malnourished rural population. Fruit trees also provide timber, fuel, fodder, fencing material and offer sustenance, apart from generation of off-season employment. Although great attention has been paid to increase productivity of horticultural crops under irrigated areas, the potential of drylands is yet to be fully tapped (Pareek, 1997).

Rainfed horticulture offers great scope for food and nutrition security. However, a production system under semi-arid environment faces several biophysical constraints like poor soil condition, limited water resource, high temperature, hot wind, high solar radiation which lead to high atmospheric vapour pressure deficit and high potential evapotranspiration (Boyer, 1969; Pareek, 1997). The growth and productivity of fruit trees can be greatly enhanced by improving moisture retention capacity of soils for making water available to plants for longer period (Gupta *et al.,* 2000; Rao *et al.,* 2000). Many methods such as microsite improvement, development of micro-catchment areas, trenching, ponding of water and mulching are followed to conserve moisture for a longer time in the root zone of the plant (Hegde and Srinivas, 1989). The inherent capacity of soil for retention of water could be improved with addition of organic matter and tank silt.

The use of bentonite and other clay minerals for increasing water retention in sub-surface soil in dryland horticulture was reported by many workers (Chaudhari 1996 ; Singh *et al.,* 1988; Singh and Singh, 1988; Chadha and Pareek, 1991; Brown Kirk, 1977). The use of bentonite for moisture conservation in sub-soil boosted growing of pomegranate in desert soils (Singh *et al.,* 1988). Singh and Singh (1988) found bentonite useful for reducing percolation losses in round gourd (*Citrullus vulgaris*) under sandy soils. Spray of kaolinite (1-5%) as antitranspirant after post-monsoon rain was proved effective in conserving plant water (Chadha and Pareek, 1991; Reddy and Khan, 2000; Kadbane and Mungse; 1998). In the present study, addition of clay minerals with high water holding capacity and cation exchange capacity was attempted to improve establishment and yield of horticultural tree species in Alfisols.

Materials and Methods

Field experiments were conducted on custard apple 'Balanagar selection' variety during 1998-2000 at Hayathnagar Research Farm of CRIDA, Hyderabad to assess morphological and physiological growth parameters on 8 different days after planting (DAP) with 4 levels of clay mineral application. The amount of clay mineral was determined in order to get a final clay content of 20, 25 and 30% of volume of the pit. Application of clay mineral dose of more than 4.8 kg/pit would lead to a final clay content of more than 30% which is not beneficial since it will drastically affect the growth of custard apple (Osman *et al.,* 1997). Accordingly, clay mineral levels of 0, 1.2, 2.4 and 4.8 kg/pit were tested in Randomized Block Design with 8 replications. In the treatments, Fullers Earth as a soil clay mineral was used as pit mixture. The Fullers earth, a naturally available soil clay mineral in parts of Ranga Reddy district of Andhra Pradesh was procured from Srinivasa Minerals and Chemicals, Hyderabad. It has a mineral composition of Attapulgite/Polygorskite, Montmorillonite and Quartz; pH of 8.5; CEC of 92.52 C mol (P^+)/kg; bulk density of 0.53 g cm^{-3}; Calcium of 134.1 ppm;

Potassium of 55.78 ppm; moisture of 65.2% at 0.33 bar; moisture of 59.1% at 15 bar; available water of 6.1%. Pits of size 45 x 45 x 45 cm were dug at a spacing of 5 x 5 m. The pits were filled back after thorough mixing the original soil, FYM @ 20 kg/pit + DAP @ 100 g/pit and calculated doses of clay mineral as per the treatments. Healthy grafts of the variety 'Balanagar selection' uniform in height were procured from Agri-Horticultural Society, Hyderabad. The planting was taken up on 4-8-1998 on a rainy day and the experiment was carried out under rainfed conditions.

The study involved 8 trees as replications for each treatment. Observations on plant morphological and physiological parameters in custard apple were recorded in each plot with clay mineral modification and control at different days after planting. The morphological observations recorded were : tree height (cm) and number of branches at 0, 36, 102, 158, 237, 300, 439 and 704 DAP, while spread (cm) was recorded on 439 and 704 DAP in east-west and north-south directions. Tree girth (cm) was recorded at 704 DAP. Observations on physiological parameters like stomatal conductance (cm/sec) and relative water content (%) were recorded at 158 DAP, while canopy temperature (°C) was recorded at 158 and 260 DAP. Based on ANOVA, the clay mineral treatments were tested for effect on different traits. The relationship between different traits along with weather variables were derived. Regression models were constructed for predicting change in (a) height, number of branches, spread and girth through clay mineral application; and (b) height and number of branches over a period of time. Based on the study, the usefulness of clay mineral application on different traits in custard apple is assessed.

Results and Discussion

Particle size analysis of soil after amending with clay mineral

The results of particle size analysis viz., sand (%), silt (%) and clay (%) in 0-15 and 15-30 cm of depth in the amended soil for custard apple (360 DAP) are given in Table 1. The sand (%) decreased with addition of clay mineral in both depths. It ranged from 50% in 4.8 kg/pit application to 75% in control in 0-15 cm depth, while it ranged from 58 to 81% in the corresponding treatments in 15-30 cm depth. The silt (%) increased with addition of clay mineral in both depths. It ranged from 10% in control to 21% with application of 2.4 kg/pit in 0-15 cm depth, while it ranged from 5 to 17% in the corresponding treatments in 15-30 depth. The clay (%) increased with addition of clay mineral in both depths. It ranged from 15% in control to 33% in 4.8 kg/pit application in 0-15 cm depth, while it ranged from 14 to 28% in the corresponding treatments in 15-30 cm depth.

Changes in physico-chemical constituents of soil after amendment with clay mineral

The mean change in physico-chemical characteristics of soil in 0-15 and 15-30 cm depth of bulk density, pH and CEC with addition of clay mineral based on replicated samples are given in Table 1. The bulk density decreased with addition of clay mineral. It ranged from 1.44 g/cc in 4.8 kg/pit to 1.7 g/cc in control in 0-15 cm depth, while it ranged from 1.36 to 1.42 g/cc in the corresponding treatments in 15-30 cm depth. The soil pH increased with addition of clay mineral. It ranged from 5.9 in control to 6.8 in 1.2 kg/pit application in 0-15 cm depth, while it

Table 1 : Particle size analysis and physico-chemical constituents of amended soil

Variable (Depth)	Clay mineral treatment			
	Control	1.2 kg/pit	2.4 kg/pit	4.8 kg/pit
Sand (%) (0-15 cm)	75	65	57	50
Sand (%) (15-30 cm)	81	64	60	58
Silt (%) (0-15 cm)	10	15	21	17
Silt (%) (15-30 cm)	5	10	17	14
Clay (%) (0-15 cm)	15	20	22	33
Clay (%) (15-30 cm)	14	26	23	28
pH (0-15 cm)	5.9	6.8	6.7	6.3
pH (15-30 cm)	5.9	6.4	6.2	6.1
Bulk density (0-15 cm)	1.70	1.49	1.46	1.44
Bulk density (15-30 cm)	1.42	1.41	1.37	1.36
CEC (0-15 cm)	8.8	9.2	14.5	19.9
CEC (15-30 cm)	6.5	8.7	15.5	20.2

CEC : Cation exchange capacity (C mol (P^+)/kg) ranged from 5.9 to 6.4 in the corresponding treatments in 15-30 cm depth. The CEC increased with addition of clay mineral. It ranged from 8.8 C mol (P^+)/kg in control to 19.9 C mol (P^+)/kg in 4.8 kg/pit in 0-15 cm depth, while it ranged from 6.5 to 20.2 C mol (P^+)/kg in the corresponding treatments in 15-30 cm depth. The increase in CEC and pH is attributed to increase in finer fractions through clay mineral application. The decrease in bulk density increased pore space resulting in improved movement of air and water in the root zone of plant (Brady and Weil, 2001).

Effect of clay mineral application on morphological characters

Height (cm)

The height (cm) of custard apple recorded on different dates is given in Table 2. The ANOVA indicated that height of custard apple was not influenced by clay mineral application in the 1st year of establishment. There was no significant increase in height up to 300 DAP in different treatments. However, there was a significant increase in height by the end of 2nd year (439 DAP) and during 3rd year (704 DAP). The differences in height of plants between control and 1.2, 2.4 and 4.8 kg/pit application were 13.87, 28.50 and 37.75 cm, respectively at the end of 705 DAP. The mean height increased from 61.55 to 108.13 cm in control, 69.59 to 122 cm in 1.2 kg/pit, 71.65 to 136.63 cm in 2.4 kg/pit and 65.52 to 145.88 cm in 4.8 kg/pit over different dates. There was a maximum difference of 37.75 cm between 4.8 kg/pit and control at 704 DAP compared to 10.1 cm between 2.4 kg/pit and control at the start of the study. There was a variation in the response of treatments due to the fact that any clay amendment added to the pit would take some time to stabilize and provide advantage. The increment in growth attained from the DAP to the end of second year was significant in plants receiving clay mineral compared to control.

Number of branches

The number of branches in custard apple were not influenced during the 1st year of establishment; while there was a significant increase by the end of 2nd year (439 DAP) and during 3rd year (704 DAP). Maximum number of branches developed with application of 4.8 kg/pit of clay mineral. The difference in number of branches between control and 1.2, 2.4 and 4.8 kg/pit of clay mineral were 19, 42 and 100, respectively. The mean number of branches increased from 2.37 to 76.63 in control, 2.13 to 95.63 in 1.2 kg/pit, 2.13 to 118.88 in 2.4 kg/pit and 2.13 to 176 in 4.8 kg/pit. At 704 DAP, number of branches ranged between 76.63 in control and 176 in 4.8 kg/pit of application. They increased from 2.13 to 176 in 4.8 kg/pit in a period of about 22 months. The growth changes in height and number of branches are in confirmation with the results reported by Gupta (1985) and Osman and Mishra (1996).

Canopy spread

The results of spread in east-west and north-south directions observed at 439 and 704 DAP are given in Table 3, which indicated that effect of clay mineral on spread was not significant in both directions on 439 DAP, while it was significant at 704 DAP. At 704 DAP, 4.8 kg/pit of clay mineral significantly

Table 2 : Height and number of branches as influenced by clay mineral application

Clay mineral	Different dates and days after planting (DAP)							
	4-8-98	10-9-98	16-11-98	11-1-99	31-3-99	4-6-99	23-10-99	8-7-00
	0	36	102	158	237	300	439	704
Height								
Control	61.55	64.37	86.87	89.75	86.62	95.25	106.06	108.13
1.2 kg/pit	69.59	73.50	83.12	86.25	91.75	96.37	120.87	122.00
2.4 kg/pit	71.65	76.25	83.37	91.25	91.62	97.50	125.25	136.63
4.8 kg/pit	65.52	68.50	77.12	81.87	89.50	102.50	132.35	145.88
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	14.52	19.19
Number of branches								
Control	2.37	4.75	7.75	8.50	12.00	20.75	45.25	76.63
1.2 kg/pit	2.13	4.62	8.87	8.25	13.75	34.37	52.65	95.63
2.4 kg/pit	2.13	5.25	6.87	7.12	16.25	35.00	69.53	118.88
4.8 kg/pit	2.13	4.12	7.62	8.12	16.50	35.50	85.60	176.00
SEm±	0.17	1.14	1.03	1.19	1.33	4.11	6.52	15.3
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	14.61	61.3

NS: Not significant   CV: Coefficient of variation

Table 3 : Spread and girth as influenced by clay mineral application

Clay mineral	Spread (cm) on different days after planting				Girth (cm)
	23-10-1999		8-7-2000		8-7-2000
	439 days		704 days		704 days
	East-West	North-South	East-West	North-South	
Control	83.62	77.20	85.75	79.10	2.36
1.2 kg/pit	80.50	78.00	83.63	82.88	2.29
2.4 kg/pit	84.75	78.62	92.50	127.00	3.54
4.8 kg/pit	84.00	94.75	120.38	153.50	4.18
CD (P=0.05)	NS	NS	25.09	29.49	1.16

NS: Not significant

increased the spread of plants in east-west direction compared to other treatments. However, the spread was higher under north-south direction in 2.4 and 4.8 kg/pit at 704 DAP which were superior to both control and 1.2 kg/pit application. Among treatments, 4.8 kg/pit resulted in higher spread in both directions on both DAP except east-west direction at 439 DAP. Further, the treatment increased spread significantly from 84 cm on 439 DAP to 120.38 cm at 704 DAP in east-west direction and 94.75 cm at 439 DAP to 153.5 cm at 704 DAP in north-south direction. The variation was relatively higher under north-south compared to east-west direction.

Girth

The results of girth observed in different treatments at 704 DAP are given in Table 3, which indicate that the effects of clay mineral treatments on girth were significantly different from each other. The girth was significantly lower (2.36 cm) in control and 2.29 cm in 1.2 kg/pit as against 3.54 cm with 2.4 kg/pit and 4.18 cm with 4.8 kg/pit clay mineral application. However, 2.4 and 4.8 kg/pit application were at par with each other for tree girth. The differences observed in morphological traits mentioned above between the control and clay mineral treatments were due to improvement in soil physical and chemical properties such as improved structure, water holding capacity, increased CEC and availability of nutrients. The changes indicated that application of clay mineral improved the soil characteristics favourably for custard apple plant growth between 439 and 704 DAP. These results are in conformity with the findings of Gupta (1985), Singh and Vishnumurthy (1988), Osman and Mishra (1996), Romonov and Nureeva (1997).

Effect of clay mineral application on physiological characters

The stomatal conductance and relative water content (%) during stress at 158 DAP, while canopy temperature was observed at both 158 and 260 DAP are given in Table 4. It was significantly influenced by clay mineral applied to soil in the pit. A maximum stomatal conductance of 0.05 cm/sec was in 4.8 kg/pit, while a minimum of 0.01 cm/sec was observed in control. Application of 1.2 and 2.4 kg/pit of clay mineral provided a stomatal conductance of 0.02 and 0.04 cm/sec, respectively. The ANOVA indicated that the effects of clay mineral on relative water content were significantly different. The relative water content was 69.6% in 4.8 kg/pit and was at par with 2.4 kg/pit application. Both treatments were superior to control and 1.2 kg/pit application. The control gave a relative water content of 59.8%, while 1.2 kg/pit application gave 61.1%.

The canopy temperature was significantly influenced by application of clay mineral at 158 and 260 DAP. Application of 4.8 kg/pit recorded 10.8° C, while control had 11.91° C on 158 DAP. The temperature was 32.37° C and 37.38° C in 4.8 and

Table 4 : Effect of clay mineral on canopy temperature, stomatal conductance and relative water content on different days after planting (DAP)

Clay mineral	Stomatal conductance (cm/sec)	Relative water content (%)	Canopy temperature (°C) (recorded at 0800 hrs)	
	158 DAP	158 DAP	158 DAP	260 DAP
Control	0.01	59.8	11.85	37.13
1.2 kg/pit	0.02	61.1	11.91	37.38
2.4 kg/pit	0.04	67.2	8.81	32.50
4.8 kg/pit	0.05	69.6	10.8	32.37
CD (P=0.05)	0.01	3.03	1.54	0.24

1.2 kg/pit on 260 DAP, respectively. The control and 1.2 kg/pit application were at par with higher canopy temperature, while 2.4 and 4.8 kg/pit were at par with relatively lower temperature. The differences in stomatal conductance and relative water content observed during stress between 158 and 260 DAP are attributed to higher moisture content in the root zone of the plants with clay mineral application compared to control.

Estimates of correlation between different variables

Based on estimates of correlation between tree height, number of branches, minimum and maximum temperature, rainfall and relative humidity (morning and afternoon), tree height and number of branches had a positive and significant correlation of 0.80** in control; 0.91** in 1.2 kg/pit; 0.96** in 2.4 kg/pt; and 0.94** in 4.8 kg/pt. Rainfall had a positive correlation of 0.95** with rainfall and 0.89** with number of branches. There was no significant correlation of minimum and maximum temperature, relative humidity with height and number of branches in custard apple based on the study.

Based on the estimates of correlation between tree height, number of branches, spread in east-west and north-south directions, girth, stomatal conductance, relative water content and canopy temperature in custard apple on different DAP, the tree height had a significant correlation of 0.93** on 439 DAP and 0.944** at 704 DAP with number of branches; 0.95** with spread in north-south direction; 0.81* with spread in east-west direction; and 0.95** with girth at 704 DAP. The number of branches had a significant correlation of 0.86* on 439 DAP and 0.94** at 704 DAP with spread in north-south direction; 0.91** with spread at 704 DAP in east-west direction; and 0.94** with girth at 704 DAP. Girth had a significant positive correlation of 0.90** with east-west spread; and 0.95** with north-south spread at 704 DAP. Stomatal conductance had a significant positive correlation of 0.93* with relative water content; while canopy temperature had a significant negative correlation of -0.95** with stomatal conductance and -0.89* with relative water content at 158 DAP.

Table 5 : Regression coefficients of changes in height and number of branches in custard apple

Date (DAP)	α	β	R^2	σ
Height = ± α ± β (Clay mineral)				
4-8-98 (0)	65.992**	0.517	0.06	5.33
10-9-98 (36)	69.572**	0.516	0.04	6.33
16-11-98 (102)	86.620**	-1.905*	0.93**	1.31
11-1-99 (158)	90.226**	-1.403	0.48	3.70
31-3-99 (237)	89.096**	0.370	0.10	2.79
4-6-99 (300)	94.698**	1.527*	0.96**	0.81
23-10-99 (439)	110.564**	5.033*	0.86**	5.05
8-7-2000 (704)	111.828**	7.777*	0.92**	5.60
Number of branches = ± α ± β (Clay mineral)				
4-8-98 (0)	2.274**	-0.040	0.47	0.11
10-9-98 (36)	4.924**	-0.114	0.25	0.49
16-11-98 (102)	8.048**	-0.129	0.10	0.96
11-1-99 (158)	8.200**	-0.096	0.11	0.70
31-3-99 (237)	12.650**	0.940*	0.81**	1.15
4-6-99 (300)	2.610**	2.527	0.53	5.98
23-10-99 (439)	44.996**	8.696**	0.97**	3.36
8-7-2000 (704)	72.806**	20.942**	0.97**	4.72
Spread (East-West) = ± α ± β (Clay mineral)				
23-10-99 (439)	82.522**	0.331	0.13	2.14
8-7-2000 (704)	79.326**	7.733*	0.87**	7.43
Spread (North-South) = ± α ± β (Clay mineral)				
23-10-99 (439)	74.294**	3.737*	0.83**	4.30
8-7-2000 (704)	75.312**	16.813*	0.92**	12.41
Girth = ± α ± β (Clay mineral)				
8-7-2000 (704)	2.204**	0.423*	0.88**	0.39

* and ** indicate significance at 5 and 1% level, respectively; DAP: Days after planting; α: Intercept; β:Slope; R^2 : Coefficient of determination; σ : Prediction error

Prediction of changes in different traits through clay mineral application

Based on regression analysis of changes in growth parameters through four clay mineral treatments, prediction equations were calibrated to assess the effect of clay mineral application on changes in tree height, girth, number of branches and spread on different DAP. The regression coefficients of clay mineral application, coefficient of determination (R^2) and prediction error of different morphological traits are given in Table 5. The clay minerals had a significant influence on height at 102, 300, 439 and 704 DAP and number of branches at 237, 439 and 704 DAP. A maximum rate of change of 7.777 cm in height and 20.942 in number of branches with an unit change in clay mineral was observed. In case of all DAP on which there was a significant influence of clay minerals, the R^2 ranged from 0.86 to 0.96 for height and 0.81 to 0.97 for number of branches. The prediction error ranged from 0.81 cm at 300 DAP and 5.6 cm at 704 DAP for height, while it was 1.15 at 237 DAP and 4.72 at 704 DAP for number of branches. The spread in east-west direction at 704 DAP was significantly influenced by clay minerals with R^2 of 0.87 and prediction error of 7.43 cm. The spread in north-south direction at both 439 and 704 DAP were significantly influenced by clay minerals with R^2 of 0.83 and 0.92 and prediction error of 4.3 and 12.41 cm, respectively. The girth at 704 DAP was significantly influenced by clay minerals with R^2 of 0.88 and prediction error of 0.39 cm.

Conclusion

Clay mineral application improved the physical condition and water holding capacity of light textured Alfisols. Height has significant relation with number of branches (at 439 and 704 DAP) and north-south and east-west canopy spread (at 704 DAP) and girth (at 704 DAP). The number of branches had a significant correlation with north-south and east-west spread (at 704 DAP) and girth (at 704 DAP). The study indicated that application of 4.8 kg/pit of clay mineral was effective in improving height and number of branches in custard apple compared to other levels under semi-arid Alfisols.

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