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Research Paper

ENHANCING SEED PRODUCTIVITY OF PONGAMIA PINNATA L. USING SILVICULTURAL PRACTICES

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Abstract:
The evaluation of pruning and fertilizer treatments for improving the seed productivity of pongamia was carried out at three different research ranges viz. Mandya, Tumakuru and Haveri during 2016 with the objectives to standardize the pruning practices and to evaluate the manurial and fertilizer requirement for enhancing seed productivity. The pruning was done on main shoot, subsequent shoots from top to end on whole plant. The data obtained were analyzed with four different severity treatments i.e., PT1- 30 cm, PT2- 45 cm, PT3- 60 cm and PT4 (control), with three replication for each treatment. In comparison with before and after pruning, PT2 responded well with 139.83 % increase for number of shoots and 58.72 % increase for number of inflorescence at Karjagi (Haveri) field. Hence, pruning treatment of 45 cm pruning from tip of the shoot may be recommended as a silvicultural practice for enhancing number of shoots and inflorescence which in turn enhances the seed production in pongamia. Evaluation of fertilizer treatments for vegetative growth of pongamia trees were performed accordingly, the results indicated better in treatment FT2, FT6, FT7 and FT8. Based on the performance of pod and seed weight under different fertilizer treatments, treatment FT6 or FT7 may be recommended as a silvicultural practice for enhancing the seed yield in pongamia.

Keywords: *Pongamia pinnata*, Pruning, Fertilizer

INTRODUCTION:

Pongamia pinnata (L.) Pierre belongs to sub-family Papilionaceae under the tribe of Millettieae and they are commonly called as karanja tree (Rao *et al*., 2011). The species are fast growing, perennial, deciduous arboreal legumes native to subtropical regions. It is most likely to be originated from India and commonly found in India, Pakistan, Bangladesh, Malaysia, Vietnam, Thailand, Florida, Australia, and Sri Lanka and also in northeastern Australia, Japan, Fiji, and the Philippines (Mukta and Sreevalli, 2010). It is medium sized evergreen tree with the height upto 40 feet (Sangwan *et al*., 2010). This tree commonly found along riverbanks and also on village common lands. The seeds of Pongamia are rich source of oil (28 to 42%) and which are basically utilized for preparing biodiesel (Osman et al. 2009).

The tree is known for its multipurpose benefits in environmental management and in traditional folk medicines of Ayurveda, Siddha and Unani system of treatment (Kesari and Rangan, 2010 and Sangwan *et al*., 2010). Most importantly they are potential source of bio-diesel with advantages being free from carcinogenic ring and sulfur components, non-toxic and biodegradable (Yamane *et al*., 2006). The seeds contain 28 – 34% of oil with a higher concentration of polyunsaturated fatty acids (Kesari *et al*., 2009) with 44% oleic acid (Rao *et al*., 2011). The tree bears the fruit at the age of 6 - 7 years with 5 – 30 kgs of pods per tree per year.

Although, the species are very well suitable for different agroforestry systems, the major constraint for large scale production is lack of information and knowledge on cultivation practices (Daniel and Hegde, 2007). In comparison to Jatropha and other oil yielding species, advantages with Pongamia is its seed yield ability which is above 50 % (Daniel and Hegde, 2007). The yield of the tree, are correlated to the geographical conditions, tree age and growth performance. The factors such as frequency, intensity and periods of fruiting, as well as the factors of ages are influenced by the form of the canopy and tree size (Syamsuwida *et al*., 2015). *P. pinnata* play a significant role in the biodiesel production and environmental security. *P. pinnata* is perennial in nature and require fertilization for optimum growth, yield and quality, which is highly neglected. Nitrogen, phosphorus and potassium play a vital role in overall development of Pongamia fruits. However, the use of these nutrients through conventional methods does not meet the fertilizer requirement according to the growth stage of the tree and thereby, fertilization becomes inefficient. A clear understanding of phenological behavior in the plants, can be studied through fertilization application for better field traits (Srimathi *et al*., 2013). Fertilizers are applied for enhancing plant growth with flowering and fruiting. They help in providing additional nutrients for the plants growth and also enhance aeration and water retention capacity in soil. The micronutrients like magnesium, iron, zinc, manganese, copper, boron, molybdenum, etc are rarely applied for the plants growth systematically. At times, application of organic manure helps in combating the deficiencies in soil for the plants growth.

Few of the papers suggest that the cost effective trimming and pruning practices (Daniel and Hegde, 2007; Scott *et al*., 2008) can ensure the long term viability of the species. Pruning practices in general helps in obtaining natural shape of the tree, limit the size of a plant, remove undesirable broken, unsightly, diseased or insect-damaged growth, improve flowering by removing some branches by allowing light to penetrate to the interior of the plant. The need to standardizing planting model, to helps in avoiding the competition for nutrition among the plants and facilitates higher plant yields. So, there is an urgent need to undertake detailed research for development of management practices, high-yielding cultivars, mass multiplication techniques, suitable development models for cultivating the species (Dalemans *et al*., 2019). In addition, long term field trial across climate and also standardizing models and schedules for irrigation, pruning and fertilizer application helps in increasing financial viability for *P. pinnata* plantations as suggested by the Bhojvaid (2008) and Murphy *et al*., (2012). Few modifications in the silvicultural practices of pongamia, like application of fertilizers and pruning will lead to better yield. The objective of this study was to standardize the pruning practices and to evaluate the manurial and fertilizer requirement for enhancing seed productivity.

MATERIALS AND METHODS:

The experiment was conducted at the three different research ranges viz. Mandya, Tumakuru and Haveri of Bangalore and Dharwad research circles which was established by Karnataka Forest Department (Table 1). Forty trees of *P. pinnata* were selected for layout of experiment as per the systematic design by treating ten trees in each row for each treatment are: Pruning Treatment – 1 (PT1) – 30 cm pruning from top of shoot tip, Pruning Treatment – 2 (PT2) – 45 cm pruning from top of shoot tip, Pruning Treatment – 3 (PT3) – 60 cm pruning from top of shoot tip, Pruning Treatment – 4 (PT4) – control (not pruned) during February 2016. The observations were noted before pruning and after one/two year of pruning for height, collar diameter, crown diameter/width, number of branches/shoots and number of inflorescence.

Soil samples were collected as per V shape method. Soon after collection of soil samples, soil was analyzed for macro and micro nutrients with help of Krishi Vignan Kendra (KVK) – Indian Institute of Horticulture Research (IIHR), Herihalli. A detail of soil report is represented in table 2. Trees for application of fertilizer were selected from clonal seed orchards (CSO) Pongamia plantations during June 2016. Based on the soil analysis report (Table 2), following treatment was finalized in consultation with soil science department – GKVK, Bangalore and treatment are as follows. Forty trees of *P. pinnata* were selected for layout of experiment as per the systematic design by treating ten trees in each row for each treatment was performed. Fertilizer was applied at planting trees at certain concentration at following ratios such as: Poultry manure (10 kg/tree), Sulphur component (50, 75 and 100 g/tree), NPK was applied with varied concentration along with sulphur (1:1:1 + 50 g Sulphur/plant; 1:2:1 + 50 g Sulphur/ plant, where Sulphur is added to see the effect on oil content; 1:3:1 + 50 g Sulphur/plant), The biofertilizers was added at 3.5 g VAM + 3.5 g PSB/plant.

Observation and data analysis

Biometric observations recorded at different places of field trial were carried out for the following parameters accordingly, plant height was measured from ground level to tip whereas the collar diameter was measured at the base of the stem and expressed in cm. the pod and seed were collected and yield per tree was calculated. The crown width from north-south and east- west direction was collected. The number of inflorescences was also counted per tree. The growth observations and yield data were subjected to analysis if variance (ANOVA) to understand the significance of differences between the treatments (Gomez and Gomez, 1984) and expressed using Duncan Multiple Range Test (DMRT).

RESULTS:

The effect of pruning and mineral fertilizer on Pongamia plants carried out at three different locations of Karnataka is as follows;

Pruning

Pruning is one among the silvicultural practices resulting in inducing more number of branches, ultimately aiding in increasing inflorescences number leading to higher seed yield. In our present study, we were able to collect the number of new shoots and flower/inflorescence after pruning and results are presented in Table 3.

Kargaji (Haveri Research Range): It is evident that pruning treatments had a significant influence on vegetative traits like the shoot extension, height, collar diameter, crown width and number of branches. The pruning severity was observed to be significant in PT2, which produced maximum number of inflorescence per shoot (91.90±72.75) and however, minimum number of inflorescence per shoot (62.50±32.44) was recorded in control. Number of branches was significant after pruning was done when compared to unpruned tree i.e. 83.70±31.28.

The effect of pruning severity on height was found to be significant in treatment PT2 (45 cm from the ground) with height (225.10±59.96), followed by treatment PT1 (215.00±59.49) and lowest height was recorded with PT3 (214.40±35.66). In addition, collar diameter was found significantly maximum in treatment PT2 and PT3 i.e. 85.02±24.50 (45 cm) and 90.48±12.89 (60 cm). It also shows, the crown width (NS and EW) of *P. pinnata* which was found to be significant at PT2 (310.10±103.32 and 281.30±98.07).

Ankapura (Tumakuru Research Range): The pruning severity in reproductive traits was significant in PT2 with number of inflorescence per shoot (119.00±51.08) and minimum number of inflorescence per shoot (50.80±25.22) was recorded in PT3. Furthermore, number of branches was significant after pruning was done when compared to unpruned tree i.e. 67.50±18.61.

The effect of pruning severity on the height was found to be significant in PT2 with height (225.60±109.86) followed by treatment PT1 (224.90±54.92) and lowest height was recorded with PT3 (203.90±77.23). The effect on collar diameter was maximum with PT1 (30 cm) and PT2 (45 cm) i.e. 70.64±13.12 and 67.57±25.75. The crown width was found to be significant at PT1 (231.0±20.96 and 256.80±37.30) and minimum of was observed at PT2 i.e. 171.10±88.53 and 170.20±77.32.

CM Gudda (Mandya Research Range): It is evident that pruning treatments PT2 and PT3 had a significant influence on shoot with 379.00±76.22 and 398.50±46.07 respectively. The obtained result also showed significant effect on collar diameter in PT3 i.e. 103.49±21.48, PT4 i.e. 95.21±16.01 and PT1 i.e. 91.48±24.39. The percentage (%) increase in inflorescence was more in PT1 (90.67±12.42) and less in PT2.

Fertilizer Treatment

In today scenario, the main method to maintain/restore soil nutrients and increase crop yields is through application of mineral fertilizers. Mineral fertilizers and manure are now the main source of nutrients applied to the soil. In the present study, manurial and fertilizer at different concentrations are evaluated for enhancing seed productivity by following nine treatment application and the results are presented accordingly (Table 4).

Kargaji (Haveri Research Range): The results of evaluating the manurial and fertilizer requirement for *P. pinnata* for productivity enhancement are presented as per the ANOVA and DMRT analysis. There is a significant difference in pod and seed yield among all the nine treatments applied. Among all the treatments, FT6 was the highest with 10.8 Kg of pod yield and 4.08 Kg of seed yield per tree. This was followed by treatments FT8, FT7 and FT2. This indicates that application fertilizer like NPK is must for enhancement of productivity. In addition, number of inflorescences was highest in FT6 followed by FT2 and FT7. The trait total oil content had no much significant difference among the treatments.

Ankapura (Tumakuru Research Range): Among all the treatments, FT7 had high yield with 7.03 Kg of pod and 3.05 Kg of seed yield per tree. Treatment FT6, FT8 and FT2 respectively gave higher yield when compared rest other treatments. Number of inflorescences was highest in FT8 followed by FT7 and FT6.

CM Gudda (Mandya Research Range): The results are not presented on pod and seed yield, as the pod set failed because of drying and gall formation in flowers in this particular location.

DISCUSSIONS:

Pruning and application of fertilizers are the important aspects for obtaining better quality yield under mass scale production. Malik (1994) reported that the pruning produces maximum and good quality seeds balancing between fruiting and vegetative hood. Most of the earlier studies reported varied effects on yield after pruning (Dahapute et al., 2018). Results obtained in our study are in similar lines with the study conducted by Santoso et al., 2016 in *Jatropha curcas* that pruning has a potential agronomical practice to achieve a higher yield through improving crop management conditions. Gour (2006) also suggested cutting down the trees to 45 cm stumps improve yield in Jatropha. The total pruning every year seems not to be necessary. They can be pruned totally when plants are too tall with non-productive inflorescence, which intern leads to harvest with lower seed yield. For newly-established plantation of Jatropha, pruning the main branch (stem) at 30-45 cm is ideal for maximizing the growth rate for optimizing the number of primary and secondary branches (Behera et al., 2010). In this study, the three-year old stumps of 50 cm were too short and caused lower fruit yield and seed yield than the stumps of 70 and 90 cm. The stumps of 70 cm were most productive. The contrasting results could be possibly due the difference in ages of the trees. Gour (2006) also suggested cutting 2/3 of the terminal branches of Jatropha for each successive year. Furthermore, number of branches also showed maximum consistency in PT1 i.e. 271.60±73.07. The pruning severity in reproductive traits was observed to be significant in PT2 for producing maximum number of inflorescence per shoot (111.07±19.28) and however, minimum number of inflorescence per shoot (73.00±17.97) was recorded at control.

In the present study, the terminal branches were not cut in the second year, but fruit yield and seed yield were higher than those in the first year. Every year pruning seems not to be necessary as the tree will be too tall and the branches will be too long that causes mutual shading and low yield and harvest can be difficult. *P. pinnata* being a biodiesel crop requires nutrients for production of seeds on a sustainable basis. Added to this, it is a well-known fact that manurial and fertilizer constitutes a dependable source of essential nutrients besides improves soil conditions. The main method to maintain and restore soil nutrients and increase crop yields is through application of mineral fertilizers such as nitrogen (N), Phosphorous (P) and Potassium (K). The N, P, K used in commercial fertilizers is easily soluble and can be assimilated by plants. Because of the simplicity of its storage and handling, N, P, K can easily be applied when plants need it most. In developed countries, mineral fertilizers are the main source of NPK applied to crops, followed closely by livestock manure. Manures are the second in nutrient inputs to agricultural land. The nutrient content of manure varies from one country to another and from one region to another within the same country. It depends on the type of farming, grazing systems and nutrient content of different foods and fodder for livestock (Bouldin et al., 1984; Maguire et al., 2011).

Optimal fertilization can increase the seed and oil yield, but high fertilization can induce high biomass but low seed production (Achten et al., 2008). Nitrogen is comparatively more mobile nutrient and taken up by trees through mass flow, whereas, less mobile nutrients like phosphorus and potassium are absorbed by the process of diffusion (Barber, 1995; Mmolawa and Or, 2000). The fruit physical parameters, *viz*. weight, length, volume, firmness, pulp content and yield attributing characters are prime indicators in economics of the experiment. Application of fertilizers significantly affects the physical parameters including yield as expressed in our study on pongamia. Similarly Suriharn et al., (2011) conducted fertilizer experiment in jatropha and found that, application of fertilizer at the rate of 312 kg ha^{-1} have the highest number of branches (27 branches) followed by 625 kg ha^{-1} (23 branches) and 0 kg ha^{-1} (21 branches), respectively. Application of fertilizer at the rate of 312.5 kg ha^{-1} also gave the highest branch length (90.7 cm) followed by 625 kg ha^{-1} (82.9 cm) and 0 kg ha^{-1} (74.9 cm), respectively. Application of fertilizer to tree-year old physic nut is also recommended but the application rate should not be higher than 312.5 kg ha^{-1} and the recommended rate should be dependent on soil analysis. Application of fertilizer at the rate higher than 312.5 kg ha^{-1} will not be profitable.

Fertigation in *P. pinnata* plantations have proved to be advantages for producing higher yield per tree. Lack of efficient fertilizer management practices are one of the main issues contributing low production in *P. pinnata*. Fertigation holds a great potential since it effects and improves the growth and yield parameters of the pongamia. Considering the limited potential of resources (fertilizers), it has become essential to adopt such technologies so as to avoid the demand and stress in the future. Therefore, fertigation practice becomes efficient tool for increasing the production and productivity of the pongamia and proved beyond doubt about its utility for sustainable seed production.

In our study *P. pinnata* is better in treatment FT2 (poultry manure), FT6 (NPK 1:1:1 + 50 g Sulphur/plant), FT7 (NPK 1:2:1 + 50 g Sulphur/plant) and FT8 (NPK 1:3:1 + 50 g Sulphur/plant).

CONCLUSIONS:

From the results of this study, it could be concluded that *Pongamia pinnata* responded well for pruning trails with the treatments; PT1 (30 cm pruning from top of shoot tip), PT2 (45 cm pruning from top of shoot tip) and PT3 (60 cm pruning from top of shoot tip). Among all the pruning treatments PT2 (45 cm pruning from top of shoot tip) responded very well in all the three locations of Karjagi (Haveri), Ankapura (Tumakuru) and C.M. Gudda (Mandya). In comparison with before and after pruning, PT2 (45 cm pruning from top of shoot tip) responded well with 139.83 % increase for number of shoots and 58.72 % increase for number of inflorescence at Karjagi field; 96.33 % increase in number of shoots and 70.32 % increase for number of inflorescence at Ankapura field and 91.24 % increase for number of shoots and 45 % increase for number of inflorescence at C.M. Gudda field. Hence, pruning treatment of 45 cm pruning from tip of the shoot may be recommended as a silvicultural practice for enhancing number of shoots and inflorescence which in turn enhances the seed production in Pongamia. Evaluation of fertilizer treatments for vegetative growth in all the three locations (Karjagi, Ankapura and C.M. Gudda) have indicated that, of the mean performance of *Pongamia pinnata* is better in treatment FT2 (poultry manure), FT6 (NPK 1:1:1 + 50 g Sulphur/plant), FT7 (NPK 1:2:1 + 50 g Sulphur/plant) and FT8 (NPK 1:3:1 + 50 g Sulphur/plant). Mean performance of *Pongamia pinnata* for pod and seed weight expressed significant difference among all the fertilizer treatments both at Ankapura and Karjagi field. Based on the performance of pod and seed weight under different fertilizer treatments, treatment FT6 (NPK 1:1:1 + 50 g Sulphur/plant) or FT7 (NPK 1:2:1 + 50 g Sulphur/plant) may be recommended as a silvicultural practice for enhancing the seed yield in pongamia.

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Table 1: Details of research range selected for pruning and fertilizer trial.

Circle		Range	Zone	Place/village	Latitude	Longitude
1	Bangalore	Mandya	Southern Dry Zone	CM Gudda	12° 45' 15" N	77° 57' E
2	Bangalore	Tumakuru	Central Dry Zone	Ankapura	13° 00' 42" N	77° 34' 8" E
3	Dharwad	Haveri	Northern Transition Zone	Karjagi	14° 49' 15.85" N	75° 26' 09.92" E

Table 2: Report on soil analysis.

Parameters	Units	Critical limit	Haveri range	Mandya range	Tumakuru range
pH	1:2.5	6.5-7.5	6.70	6.90	7.00
EC	dSm^{-1}	< 1	0.39	0.80	0.58
OC	%	0.7-1.0	0.80	0.80	0.40
N	ppm	125-180	129.00	129.00	94.00
P	ppm	5-10	24.20	3.10	20.30
K	ppm	62-125	275.00	225.00	231.00
Ca	ppm	800-1500	1260.00	917.00	961.00
Mg	ppm	150-250	639.00	501.00	172.00
S	ppm	10-15	3.90	3.60	4.90
Fe	ppm	5-10	16.70	16.70	16.60
Mn	ppm	3-8	4.10	3.90	4.50
Zn	ppm	0.75-1.0	0.10	0.30	0.30
Cu	ppm	0.5-1.0	0.10	0.30	0.30

Table 3: Mean performance of *P. pinnata* trees under pruning trial at all the 3 locations.

Pruning Treatment	Height (cm)	C. diameter (cm)	Crown width (cm)		No. of branches/shoots	No. of inflorescences
			NS	EW		
Karjagi (Haveri Research Range)						
Before pruning						
PT1 – 30 cm	193.35 ± 41.58	73.29 ± 18.74	249.70 ± 96.52	227.70 ± 59.86	37.20 ± 15.32	63.91 ± 47.85
PT2 – 45 cm	200.10 ± 65.10	77.46 ± 18.14	294.10 ± 103.74	269.60 ± 98.92	34.90 ± 16.03	57.90 ± 45.68
PT3 – 60 cm	196.50 ± 38.88	80.34 ± 10.71	257.20 ± 35.81	229.40 ± 61.11	27.70 ± 6.52	49.56 ± 43.19
PT4 – Control	196.00 ± 25.79	77.03 ± 6.19	267.00 ± 39.22	242.00 ± 30.23	33.00 ± 6.20	57.00 ± 29.11
After pruning						
PT1 – 30 cm	215.00 ± 59.49	81.52 ± 21.41	270.50 ± 91.50	242.80 ± 60.59	75.00 ± 36.06	90.40 ± 67.78
PT2 – 45 cm	225.10 ± 59.96	85.02 ± 24.50	310.10 ± 103.32	281.30 ± 98.07	83.70 ± 31.28	91.90 ± 72.75
PT3 – 60 cm	214.40 ± 35.66	90.48 ± 12.89	271.10 ± 35.89	240.50 ± 60.64	41.50 ± 15.02	63.20 ± 55.13
PT4 – Control	218.00 ± 30.23	85.67 ± 9.36	283.00 ± 39.97	254.00 ± 31.37	36.40 ± 5.08	62.50 ± 32.44
Percent increase (%)						
PT1 – 30 cm	11.20	11.23	8.33	6.63	101.61	41.45
PT2 – 45 cm	12.49	9.76	5.44	4.34	139.83	58.72
PT3 – 60 cm	9.11	12.62	5.40	4.84	49.82	27.52
PT4 – Control	11.23	11.22	6.00	4.96	10.30	9.65
Ankapura (Tumakuru Research Range)						
Before pruning						
PT1 – 30 cm	204.10 ± 60.50	64.22 ± 12.75	219.80 ± 20.84	246.80 ± 39.64	35.10 ± 11.58	56.06 ± 36.78
PT2 – 45 cm	208.80 ± 101.92	65.73 ± 17.63	159.70 ± 89.73	157.60 ± 79.46	24.50 ± 16.34	69.87 ± 46.34
PT3 – 60 cm	188.40 ± 74.36	50.97 ± 21.38	212.90 ± 116.72	200.40 ± 35.35	24.00 ± 15.15	43.56 ± 35.45
PT4 – Control	200.00 ± 42.55	60.31 ± 12.29	197.00 ± 57.61	201.00 ± 57.08	27.00 ± 10.99	56.00 ± 28.01
After pruning						
PT1 – 30 cm	224.90 ± 54.92	70.64 ± 13.12	231.80 ± 20.96	256.80 ± 37.30	67.50 ± 18.61	74.10 ± 48.40
PT2 – 45 cm	225.60 ± 109.86	67.57 ± 25.75	171.10 ± 88.53	170.20 ± 77.32	48.10 ± 33.06	119.00 ± 51.08
PT3 – 60 cm	203.90 ± 77.23	55.81 ± 25.55	227.40 ± 115.61	212.20 ± 105.23	36.90 ± 17.43	50.80 ± 25.22
PT4 – Control	218.00 ± 42.28	64.68 ± 14.35	210.00 ± 57.00	213.07 ± 55.93	34.20 ± 17.84	61.00 ± 43.31

Per cent increase (%)						
PT1 – 30 cm	10.19	10.00	5.46	4.05	92.31	32.11
PT2 – 45 cm	8.05	02.80	7.14	7.99	96.33	70.32
PT3 – 60 cm	8.23	9.50	6.81	5.89	53.75	16.62
PT4 – Control	9.00	7.25	6.60	6.01	26.67	8.93
CM Gudda (Mandya research range)						
Before pruning						
PT1 – 30 cm	324.00 ± 73.21	82.89 ± 23.93	298.10 ± 61.42	318.00 ± 86.27	161.10 ± 55.20	60.40 ± 15.95
PT2 – 45 cm	356.00 ± 44.52	88.28 ± 12.42	276.10 ± 42.55	259.80 ± 56.34	82.20 ± 14.57	76.60 ± 13.26
PT3 – 60 cm	380.00 ± 51.42	96.41 ± 16.93	367.40 ± 72.38	359.80 ± 86.61	95.20 ± 20.50	69.46 ± 18.33
PT4 – Control	353.00 ± 35.49	89.19 ± 12.63	313.00 ± 49.76	312.53 ± 66.26	106.17 ± 43.07	68.87 ± 9.41
After pruning						
PT1 – 30 cm	360.00 ± 73.03	91.48 ± 24.39	311.30 ± 63.77	333.70 ± 85.58	271.60 ± 73.07	91.50 ± 30.86
PT2 – 45 cm	379.00 ± 76.22	90.67 ± 12.42	292.10 ± 45.35	277.20 ± 56.77	157.20 ± 33.47	111.07 ± 19.28
PT3 – 60 cm	398.50 ± 46.07	103.49 ± 21.84	377.20 ± 77.42	371.60 ± 85.40	144.20 ± 35.90	79.10 ± 19.11
PT4 – Control	365.00 ± 38.08	95.21 ± 16.01	316.00 ± 49.31	317.00 ± 64.13	118.00 ± 51.00	73.00 ± 17.97
Per cent increase (%)						
PT1 – 30 cm	11.11	10.36	4.43	4.94	68.59	51.49
PT2 – 45 cm	6.46	2.71	5.80	6.70	91.24	45.00
PT3 – 60 cm	4.87	7.34	2.67	3.28	51.47	13.88
PT4 – Control	3.40	6.75	0.96	1.43	11.14	6.00

Table 4: Mean performance of *P. pinnata* under different fertilizer treatment at Karjagi and Ankapura range

Treatments	Pod weight (Kg)	Seed weight (Kg)	Oil percent (%)	Remarks
Karjagi (Haveri Research Range)				
FT1	1.793^{d}	0.803^{c}	29.447^{b}	Control
FT2	8.973^{bc}	3.433^{b}	28.867^{b}	Poultry manure – 10 Kg/plant
FT3	1.573^{d}	0.657^{c}	32.700^{ab}	50 gram Sulphur/plant
FT4	1.807^{d}	0.790^{c}	34.187^{a}	75 gram Sulphur/plant
FT5	1.843^{d}	0.700^{c}	30.067^{b}	100 gram Sulphur/plant
FT6	10.800^{a}	4.087^{a}	28.833^{b}	NPK 1:1: 1 + 50 g Sulphur/plant
FT7	8.550^{c}	3.443^{b}	28.967^{b}	NPK 1:2: 1 + 50 g Sulphur/plant
FT8	10.364^{ab}	3.290^{b}	30.100^{b}	NPK 1:3:1 + 50 g Sulphur/plant
FT9	2.643^{d}	1.067^{c}	31.707^{ab}	3.5 gm VAM + 3.5 gm PSB/plant
Mean	5.372	2.030	30.541	
SEM	0.777	0.277	0.468	
CD 5%	1.48	0.519	3.448	
Ankapura (Tumakuru Research Range)				
FT1	1.000^{b}	0.493^{c}	29.50^{a}	Control
FT2	4.103^{ab}	1.987^{abc}	31.37^{a}	Poultry manure – 10 Kg/plant
FT3	1.197^{b}	0.533^{c}	32.77^{a}	50 gram Sulphur/plant
FT4	1.347^{b}	0.600^{c}	33.80^{a}	75 gram Sulphur/plant
FT5	1.337^{b}	0.707^{c}	32.57^{a}	100 gram Sulphur/plant
FT6	5.493^{ab}	2.510^{ab}	34.30^{a}	NPK 1:1: 1 + 50 g Sulphur/plant
FT7	7.033^{a}	3.057^{a}	30.60^{a}	NPK 1:2: 1 + 50 g Sulphur/plant
FT8	3.970^{ab}	1.673^{abc}	32.23^{a}	NPK 1:3:1 + 50 g Sulphur/plant
FT9	1.483^{b}	0.807^{bc}	32.73^{a}	3.5 gm VAM + 3.5 gm PSB/plant
Mean	2.996	1.374	32.207	
SEM	0.554	0.233	0.501	
CD 5%	4.081	1.633	4.443	

Treatment means not followed by the same superscript letter and significantly different at $p = 0.05$