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Review article

A CRITICAL REVIEW ON INTEGRATED NUTRIENT MANAGEMENT IN *PONGAMIA*+CASTOR AGRI-SILVI SYSTEM

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Intercropping of agricultural crops with woody species is an age-old practice in traditional farming systems in the tropics. Food production is the major aim of subsistence farmers with most of their farmland being allocated to food crops rather than to trees and shrubs. Due to increasing population and scarcity of productive lands that cannot sustain intensive exploitation, one method that has been proposed to enhance the sustainability of agricultural production is the growing of trees in association with crops.

Alley cropping is an agroforestry system in which food crops are grown in alleys formed by hedge rows of trees or shrubs and these hedge rows are kept pruned during the rainy season. The hedge rows are usually cut to a height of about 2 m when crops are sown and kept pruned to reduce competition with crops. Work done on alley cropping in *Pongamia pinnata* was less in India and other countries. However, the available literature pertaining to tree crop competition studies, growth and yield of arable crops with tree species in alley cropping system, effect of organic and inorganic fertilizers on the growth and yield of castor, soil physical and chemical properties, availability and plant nutrient uptake and economics were briefly reviewed in this chapter under appropriate heads.

I Tree Crop Competition studies in Agri-silviculture system

Agro forestry experiments involving forestry tree species *Casuarina equisetifolia* and *Leucaena leucocephala* and arable crops sunflower, sesame and groundnut resulted in significant reduction in intercrop yields primarily due to reduced light interception [55]. Likewise, [24] reported that *Hardwickia binata* canopy reduced the mean sunlight transmission on the castor crop grown in alleys. However, higher yield was recorded from central rows with reduction in yield towards the tree. Similarly, in a study conducted at Jhansi on the tree-crop interaction in *Albizia procera* and black gram and mustard agrisilvi system it was noticed that significant reduction in the crop yield due to the limited availability of light to the crop [37]. [62] Opined that pole bean was most appropriate intercrop in six month old sesbania plantation in comparison to maize. On the other hand [58] revealed that maize yields under *Hardwickia binata* were enhanced due to improved soil fertility, lower bulk density and pH. Likewise, [43] observed higher drymatter, crop growth rate, leaf area and leaf area index in groundnut under alley cropping with *Albizia* than in sole cropping.

II Performance of Arable crops in Alley Cropping System

Studies conducted at CRIDA, Hyderabad on alley cropping with *Leucaena leucocephala* revealed significant reduction in crop yields of pigeonpea and castor (61-62%), sorghum (48%) and pearlmillet (30%). This was primarily attributed to rooting pattern of agricultural crops affecting the nutrient and moisture relations (Singh *et al.*, 1987). Likewise, [4] reported that higher grain yields of pearl millet and sorghum in *Leucaena leucocephala* alley cropping. [59] Conducted experiment in alley cropping with *Faidherbia albida* at Hyderabad the results revealed that plant height, dry matter production, crop growth rate, leaf area, leaf area index of castor were found significantly superior to sole crop of castor. Likewise, the work of [29] revealed that castor had significantly higher plant height, dry matter production, crop growth rate and leaf area index when alley cropped with *Leucaena leucocephala* than the values noticed in sole castor. Further, [6] observed better performance of rainfed castor alley cropped with *Leucaena leucocephala* in terms of dry matter production and crop growth rate than the sole cropping of castor.

Whereas, [8] conducted an experiment at Jhansi to study the effects of stand density of *Hardwickia binata* on intercrops *viz.,* soybean and mustard. Yields of intercrops were moderate but not more than the yields obtained under sole cropping. Studies conducted on the performance of soybean under tree species *viz., Prunus domestica, Morus alba* and *Punica granatum* at Solan (HP) revealed that crop yield in close proximity to tree species was minimum and the yield increased with the increase in distance from the tree [52]. In a study on alleycropping of wheat with *Morus alba* hedge rows under rainfed conditions at Solan (HP) it was observed that adverse effect on photosynthesis, transpiration and water use efficiency of wheat was attributed to the shade effect of *Morus alba* [57]. Studies conducted on production potential of sorghum, cowpea, groundnut, dhaincha, moongbean and turmeric in alley cropping with poplar recorded significant reduction in the yield of all the test crops due to the decreased light availability to crops under poplar [34]. According to [5] intercropping of castor with crops like sunflower, sorghum, soybean, pearl millet and green gram reduced the plant height, phytomass accumulation, nutrient uptake and seed yield of castor.

III Effect of organic and inorganic fertilizers on growth and yield of castor

Effect on Growth

Narasimhaiah [35] conducted an experiment to study the growth and yield of castor under rainfed conditions and revealed that drymatter production was increased progressively up to 120 DAS. Thereafter senescence was noticed and dry matter production declined till harvest in castor. [47] conducted a study on the effect of different organic materials as a source of nitrogen in castor at the Central Research Institute for Dryland Agriculture, Hyderabad and reported that application of 100 kg N ha^{-1} to the castor recorded significantly higher drymatter accumulation over the application of 50 kg N ha^{-1}, 25 kg N ha^{-1} and control treatment at all the stages of crop growth and application of *Glyricidia* as the source of nitrogen produced significantly higher plant height, drymatter accumulation and leaf area over the usage of *Leucaena*, urea and pearl millet as N source. Similarly, [6] conducted an experiment on the productivity of rainfed castor (*Ricinus communis* L.) alley cropped with white popinac (*Leucaena leucocephala*) and reported that when nitrogen was applied in combination with green leaf manure, increased plant height, dry matter production and leaf area were observed in castor when compared to without green leaf manure and significantly higher drymatter production of castor was recorded at 80 kg N ha^{-1} over the 40 kg N ha^{-1} and control treatment. These results were in agreement with the findings of Sesha Saila [39]. Similarly, in an experiment conducted to study the effect of nitrogen levels on growth and yield of castor it was reported that crop fertilized with 100 kg N ha^{-1} recorded significantly higher plant height, number of branches per plant over 75 kg N ha^{-1} and 50 kg N ha^{-1}[20]. Contrary to the above, [42] reported that significant difference were not noticed in the drymatter production of castor with the application of different levels of N *viz.,* 0, 30 60 and 90 kg N ha^{-1}.

Effect on Yield

In an experiment conducted to study the effect of nitrogen levels on the yield of castor in sandy loam soils at Palem significantly higher seed yield at 90 kg N ha^{-1} and 60 kg N ha^{-1} was observed over the control treatment [27]. Likewise, [7] conducted an experiment to study the effect of different levels of nitrogen application on the yield of castor intercropped in Subabul alleys and noticed that there was significant increase in the seed yield of castor with increased levels of nitrogen application from 0 to 80 kg N ha^{-1}. [32] recorded significantly higher castor seed yield with the application of 100 kg N ha^{-1} over 30 kg N ha^{-1} and control treatment and on par with 50 kg N ha^{-1} and 75 kg N ha^{-1}. Similarly, [42] reported that significantly higher seed yield of castor was recorded with application of 60 kg N ha^{-1} and 90 kg N ha^{-1} over the control treatment. Likewise, application of 80 Kg N ha^{-1} recorded significantly higher seed yield as compared to 40 Kg N ha^{-1} [39]. On the other hand, at Tindivanam (TN), application of FYM 5 t ha^{-1} + 100 % RDF + seed treatment with *Azospirillum* @ 50 g kg^{-1} seed resulted in significant increase in castor yield (1068 kg ha^{-1}) over 50% RDF + *Azospirillum* @ 50 g kg^{-1} seed and 50% RDF + phosphorus solubilising bacteria (PSB) @ 50 g kg^{-1} seed (646 kg ha^{-1}) (DOR,1994). Likewise, [2] conducted an experiment to study the effect of integrated nutrient management on rainfed castor and reported that conjunctive use of 0.25 t ha^{-1} neem cake + 100% RDF + seed inoculation with PSB @ 50 g kg^{-1} seed resulted in significantly higher seed yield over 0.25 t ha^{-1} neem cake + 100% RDF and 5 t ha^{-1} FYM + 100% RDF. Similarly in Andhra Pradesh, application of 50% RDF + *Azospirillum* seed treatment @ 2 kg ha^{-1} + 25% N through FYM gave increased castor yields under rainfed conditions [15]. Whereas, for Saurashtra region of Gujarat integrated use of 75% RDF + 25% N through FYM + seed treatment with *Azospirillum* @ 50 g kg^{-1} seed resulted in significantly higher yields of castor over 100% RDF, while for North Gujarat 75% RDF + 25% N through FYM + seed treatment with *Azospirillum*@50 g kg^{-1} seed + PSB @ 50 g kg^{-1} seed gave significantly higher yields over 100% RDF [16].

Similar observations were made by [40] that the application of 50% RDF in conjugation with seed treatment of *Azospirillum* @ 50 g kg^{-1}, 25% N through FYM and phosphate solubilising bacteria @ 25 kg ha^{-1} gave significantly higher seed yield of castor over 100% RDF and on par with 50% RDF + seed treatment of *Azospirillum* @ 50 g kg^{-1} seed + 25% N through FYM. Likewise, [48] opined that integrated nutrient management in castor with 75% RDF + 25% N through FYM + *Azospirillum* @ 2 Kg ha^{-1} recorded significantly higher seed yield over other treatments like 75% RDF, 100% RDF (80:40:30 Kg N:P:K ha^{-1}), 75%RDF + *Azospirillum* @ 2 Kg ha^{-1}, 75% RDF + 25% N through FYM, 100% RDF+ *Azospirillum* @ 2 Kg ha^{-1} and 100% RDF + 25% trough FYM. [28] revealed that application of FYM @ 12.5 t ha^{-1} + *Azospirillum* @ 2 kg ha^{-1}+ phosphobacteria 2 kg ha^{-1} to irrigated castor recorded significantly higher primary spike length, number of spikes per plant, number of capsules per spike and seed yield as compared to pressmud @ 2 t ha^{-1} + *Azospirillum* @ 2 kg ha^{-1} + phosphobacteria @ 2 kg ha^{-1} and sugarcane biocompost @ 1 t ha^{-1} + *Azospirillum* @ 2 kg ha^{-1} + phosphobacteria @ 2 kg ha^{-1}. These results were in agreement with the findings of [47] and [41]. Similarly, the length of primary spike was significantly higher with 75% RDF + 25% N through FYM + *Azospirillum* @ 2 kg ha^{-1} + PSB @ 2 kg ha^{-1}as compared to that of 100% RDF in irrigated castor [15]. Maheswari noticed that significantly higher spike length in castor with application of 100% N inorganic as compared to 50% N *Glyricidia* + 50% N inorganic and 50% N compost + 50% N inorganic. Contrary to the above, various integrated nutrient management practices did not record any influence on the length of primary spike [16, 18]. However, [33], [19, 42, 32, 13, 60] opined that application of increased levels of nitrogen increased the number of spikes $plant^{-1}$ in castor. On the other hand, findings of [27] showed that influence of different levels of N application i.e., 30, 60 and 90 kg N ha^{-1} to rainfed castor on number of spikes $plant^{-1}$ was significant. Further, maximum 100 seed weight of castor was obtained with 50% RDF inorganic + 25% N through castor cake + 25% N through green manure and found significantly superior to 75% RDF inorganic + 25% N through FYM [15]. However, application of 100% RDF inorganic recorded significantly higher 100 seed weight over 50% RDF under irrigated castor [16, 47] also recorded significantly higher 100 seed weight of castor with 100 kg N ha^{-1} as compared to 50 kg N ha^{-1}. Contrary to the above, the findings of [27, 2] revealed that the influence of different levels of nitrogen and integrated nutrient management practices on the 100 seed weight of castor was found non significant.

Effect on Oil Content

In an experiment conducted to study the effect of integrated nutrient management practices on the oil content of rainfed castor it was noticed that integrated nutrient management practices did not influence the oil content significantly [2]. Similar observations were also made by the other workers [13, 14, 16]. Further, [3, 25, 1, 12, 13, 14, 15, 16, 17] reported that oil content was not influenced significantly by the different nitrogen levels in castor. On the other hand, [38] opined that *Rabi* castor grown on vertic ustrochrepts of South Gujarat registered significantly higher oil yield due to application of 100 % RDN (80kg N ha^{-1}) + bio-compost @ 5 t ha^{-1} over the 100 % RDN. Similarly, in Tamilnadu, [28] noticed that application of FYM @ 12.5 t ha^{-1} + *Azospirillum*@2 kg ha^{-1} + Phosphobacteria @ 2 kg ha^{-1} to castor under irrigated conditions recorded significantly higher oil yield as compared to pressmud @ 2 t ha^{-1} + *Azospirillum*@ 2 kg ha^{-1} + phosphobacteria @ 2 kg ha^{-1} and sugarcane biocompost @ 1 t ha^{-1}+ *Azospirillum*@ 2 kg ha^{-1} + phosphobacteria@2 kg ha^{-1}. Contrary to the above, [26, 43, 32] reported that oil content in the rainfed castor decreased with increase in N application from 0 to 120 kg ha^{-1}.

IV Effect of organic and inorganic fertilizers on soil physical and chemical properties

Organic manures have been time tested materials for improving the fertility and productivity of soils. Organic manures are not just sources of nutrients, but they have profound and even some times the dominant effect on soil physical properties resulting in better structure, greater water retention, with increased infiltration more favourable environment for root growth. The beneficial effects of such properties on crop yields were rarely given due economic importance [21]. [40] Reported that the conjunctive use of organic, inorganic and biofertilizers improved the soil physical conditions and increased nutrient uptake by castor. [48] Conducted an experiment in the red sandy loam soils of Rajendranagar to study the influence of integrated nutrient management on soil physical properties in tomato-onion cropping system and the results revealed that integrated use of organic manures with inorganic fertilizers did not show any effect on the particle size distribution of soil. [36] in an experiment conducted to study the effect of integrated nutrient management on soil moisture content in cotton + greengram intercropping reported that significantly higher soil moisture content was observed in 25 kg N + 25 kg P_2O_5 ha^{-1} through inorganic fertilizers + 25 kg N ha^{-1} through FYM treatment over the inorganic fertilizers. [61] in an experiment conducted to study water productivity enhancement through integrated nutrient management in maize-wheat cropping system in rainfall areas reported that significantly higher soil moisture content was observed with 10 t ha^{-1} FYM + 10 kg N ha^{-1} over 10t ha^{-1}FYM + 30kg N ha^{-1}.

V Effect of organic and inorganic fertilizers on nutrient availability and plant nutrient uptake

Khan [(1974) reported that the available N, P and K per cent in soil and uptake of N, P and K by castor were significantly higher in N fertilized rainfed castor (80 kg ha^{-1}) over that of control. Similarly, Devi [10] reported that NPK contents of castor were significantly influenced by the levels of nitrogen application *viz.*, 20, 40 and 80 kg N ha^{-1}. Reddy [47] conducted an experiment in loamy sand soil at CRIDA, Hyderabad and observed that N uptake by castor was significantly higher at 100 kg N ha^{-1} over 25 kg N ha^{-1} and 50 kg N ha^{-1} and also observed that N uptake was significantly higher with *Glyricidia* as source of N as compared to *Leucaena* and pearlmillet. Contrary to the above, Rao and Venkateshwarlu [42] in an experiment conducted on chalka soils observed that differences in N, P, K uptake were not significant in castor with different levels of N *viz.*, 0, 30, 60 and 90 kg N ha^{-1}. Sesha Saila Sree [49] noticed that N uptake in seed increased significantly with increase in N level from 0 to 120 kg ha^{-1}. The P uptake in seed obtained with 80 kg ha^{-1} was higher compared to 0, 40 and 120 kg ha^{-1}, whereas K uptake in seed at 40, 80 and 120 kg N ha^{-1} was on par but superior to control. [23] conducted an experiment in vertisols at Dharwad to study integrated effect of organic and inorganic sources of nutrients on uptake of nutrients by sunflower and their availability after harvest and revealed that the uptake of NPK by sunflower increased with increase in the application of NPK from 50% RDF to 100% RDF and also increased with application of organic sources of nutrients. Pooran Chand [40] reported that the conjunctive use of organic, inorganic and biofertilizers increased the nutrient uptake of castor at Palem. Ravankar [44] conducted an experiment at Akola to study the effect of organic manures and inorganic fertilizers on yield and availability of nutrients under sorghum-wheat sequence and revealed that application of inorganic fertilizers in combination with organic manures increased the uptake as well as their availability in the soil. Similarly, application of FYM @ 5 t ha^{-1} significantly increased the total uptake of N, P and S in pigeonpea and groundnut [22]. Chavan [9] reported that the nitrogen uptake of castor was influenced by green manures and nitrogen levels and recorded significantly higher nitrogen uptake with green leaf manuring over without green leaf manuring and castor with *in situ* green manuring. Dhonde and Bhakare [11] conducted an experiment to study the effect of integrated nutrient management on the soil properties of vertisols and revealed that significantly higher availability of N, P_2O_5, K_2O was noticed by the application of 50% RDF inorganic + 50% through FYM as compared to 100% RDF inorganic. Likewise, Kumar and Kanjana [28] revealed that application of FYM @ 12.5 t ha^{-1} + *Azospirillum* @ 2 kg ha^{-1}+ phosphobacteria 2 kg ha^{-1} to irrigated castor recorded significantly higher N, P, K uptake as compared to pressmud @ 2 t ha^{-1} + *Azospirillum*@ 2 kg ha^{-1} + phosphobacteria @ 2 kg ha^{-1} and sugarcane biocompost @ 1 t ha^{-1} + *Azospirillum*@ 2 kg ha^{-1} + phosphobacteria @ 2 kg ha^{-1}.

VI Economic studies in agri-silviculture system

Malviya and Patel [30] reported from the experiment conducted at Saurashtra that crop yields of groundnut, greengram and blackgram with *Leucaena leucocephala* were remunerative when compared to their respective sole crops. Similarly, Singh [53] reported that gross returns were higher in alley cropped systems. Alley cropped sorghum yielded twice the income of sole sorghum whereas the alley cropped pigeonpea yielded almost seven times the income over the sole pigeonpea. Vani [59] from the study conducted at Hyderabad reported that higher net returns and benefit-cost ratio obtained from castor alley cropped in *Faidherbia albida* than sole cropped castor. Subrahmanyam [56] reported that sunflower and castor gave higher monetary returns under intercropping in young plantations of *Dalbergia sisso* when compared to sole cropping situation. Patel [39] noticed that a progressive increase in yield, net returns and benefit- cost ratio in castor with the increasing levels of nitrogen application from 0 to 80 kg N ha^{-1}. However, Baby and Reddy [2] from a study conducted at Palem in castor with different organic, inorganic and biofertilizers reported that higher net returns were obtained with the application of 0.25 t ha^{-1} neem cake +100% recommended NPK + PSB 2 kg ha^{-1} over the 0.25 t ha^{-1} neem cake + 100 % recommended NPK and 5 t ha^{-1} FYM +100 % recommended NPK. Kumar and Kanjana (2009) opined that application of FYM @ 12.5 t ha^{-1} + *Azospirillum* @ 2 kg ha^{-1} + phosphobacteria @ 2 kg ha^{-1} to castor registered higher net returns and benefit-cost ratio as compared to pressmud@2 t ha^{-1} + *Azospirillum* @ 2 kg ha^{-1} + phosphobacteria @ 2 kg ha^{-1} and sugarcane biocompost @ 1 t ha^{-1}. Sharma [51] conducted an experiment at Dharwad on shallow black soils to study the effect of integrated nutrient management on pigeonpea based intercropping system and revealed that application of 50% RDF + vermicompost @ 2.5 t ha^{-1} recorded significantly higher pigeonpea yield, gross returns and net returns over the other integrated nutrient management practices. Conservation of soil moisture and improvement of soil fertility through addition of organic materials may improve production from these lands considerably by sustaining the soil health. Hence an integrated approach of land management to utilize the natural resources more efficiently in rainfed areas is essential to meet the requirements of farmer and his livestock without deteriorating the land productivity and also generate continuous and stable income. One of the need based alternative land use system replacing the traditional farming system is a tree based system of cropping *i.e.*, agro forestry which acts as sustainable land management system especially in dryland areas.

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