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A review on genotypes, plant densities and fertilizer levels influenced on growth and yield attributes of sunnhemp

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Abstract
Sunnhemp *(Crotalaria juncea* L.) known as Indian hemp belongs to family of Fabaceae. The largest producer of sunnhemp fibre in the world is India followed by Bangladesh and Brazil. It is an important multipurpose leguminous crop grown for fibre, green manure and fodder purposes. The experiments revealed that the response of growth and yield attributes of sunnhemp were greatly pronounced by genotypes, plant densities and fertilizers. The optimum plant population with suitable genotypes under required level of fertilizers.

Keywords: Genotypes, plant densities, fertilizer, influenced

Introduction
Sunnhemp (*Crotalaria juncea* L.) is dual crop such as green manure crop and also fibre crop. India ranks first in terms of area (27 per cent) and production (23 per cent) in sunnhemp. Current yearly production of sunnhemp fibre in India is around 18.8 thousand tonnes from 0.31 lakh hectare distributed in states like Orissa, Bihar, Madhya Pradesh, Rajasthan, West Bengal, Uttar Pradesh, Maharashtra, Tamil Nadu and Jharkhand (Sarkar *et al.*, 2015) [65]. The average seed yield of Sunnhemp in India is 730 kg ha^{-1} (India Agristat, 2015) [30]. It is evident that because of shrinkage in area, production of fibre declined drastically in all states. At present, Orissa (41 per cent) and Tamil Nadu (14 per cent) occupy the first and second position, respectively in terms of area. The total area of sunnhemp in Tamil Nadu is 3.8 thousand hectares and with an average seed yield of 711 kg/ha (Sarkar *et al.*, 2015) [65].
However, sunnhemp has been losing its importance as a fibre crop due to lack of stable high yielding varieties. Though the importance of green manuring and fibre yield are well recognised but less attention was given for seed production of green manure crops. In this chapter an attempt has been made to review the salient research findings on response of different sunnhemp varieties to varied fertilizer dose and spacing on seed and fibre yield potential of sunnhemp under the relevant headings.

Performance of genotypes
In sunnhemp, varietal development is very difficult mission because it is highly cross pollinated crop. The first variety in sunnhemp K 12 black was released in 1926 by Prof T Subbnis. In the past, four varieties have been developed namely, K 12 Yellow, SH 4 (Shailesh), Swastik and Ankur. K 12 Yellow is a selection from variety K 12 Black. The varieties Shailesh (2005), Swastik (2009) and Ankur (2013) have been developed through mass selection.

Growth attributes
Tripathi *et al.* (2012) [81] reported higher plant height of 256.31cm in K-12 yellow followed by K-12 black (255.41cm). A lower value of plant height of 254.30 cm was attained with genotype T-6. Chaudhary *et al.* (2015) [8] revealed significant genotypic effect on plant height. The higher plant height was attained by the genotype SUIN 043 (245.26 cm) and SUIN 029 (243.98 cm). The highest basal diameter of 9.96 mm was recorded by the genotype SUIN 043.

Yield attributes and yield
Varieties did not differ significantly with respect to yield attributing parameters as well as fibre yield (Tripathi *et al.*, 2012) [81]. Chaudhary *et al.* (2015) [8] revealed significant genotypic effect on fibre weight. The genotype SUIN 029 recorded higher green biomass yield of 337.3 q/ha, higher stalk yield of 52.41 q/ha and higher fibre yield of 9.06 q/ha.

The genotypic effect was found to be significant on harvest index. The entry SUIN 080 was found to be the best with harvest index of 27.4 per cent. All other genotypes were on par with each other with the exception of check variety K 12 Yellow, which was recorded the least harvest index of 24.2 per cent (Tripathi *et al.*, 2012) [81]. The recently released variety Ankur produces about 10-12 q/ha fibre with good combination of fibre tenacity (21.0 g/tex) (Chaudhary *et al.*, 2015) [8].

Plant Density

The effect of plant spacing on seed yield of sunnhemp has not been comprehensively studied. Spatial arrangement of a crop on the ground is extensively renowned as one of the most important agro-techniques. Sunnhemp requires optimum space for the maximum realization of its inherent yield potential not because of its competition for actual space but because of its competition for nutrients, water, light, oxygen and carbon dioxide. However, beyond a certain limit, yield cannot be increased with increasing plant population on account of other factors coming into play. Very close spacing or higher planting density results in competition between individual plants for major nutrients, soil moisture, space and light. Decrease in the yield of individual plants at higher planting density is due to reduction in the number of pods per plant.

Thus optimum plant population is essential to obtain maximum seed yield with higher quality (Thimmanna *et al.*, 2014) [78].

Influence on plant density on growth and yield attributes in Sunnhemp

Growth attributes

The closer spacing between plants caused comparatively lesser availability of space around the plants for lateral development therefore, forced them to grow vertically. The plant height decreased gradually with increase in spacing. Higher plant height of 218.9 cm was observed under a closer spacing of 30 cm x 10 cm (Tripathi *et al.*, 2013) [82]. Similarly Thomas and Palaniappan (1998b) [80] also noticed that closer row spacing of 30 cm x 20 cm produced taller plants, higher biomass production ha^{-1} as compared to wider spacing of 45 cm x 20 cm and 60 cm x 20 cm in sunnhemp on clay loam soils. Lamani *et al.* (2010) [39] reported higher plant height in sunnhemp (172.7 cm) at the row spacing of 30 cm as compared to wider row spacing of 45 cm and 60 cm.

Spacing had significant impact on number of secondary branches/plant in sunnhemp. Lamani *et al.* (2010) [39] also observed more number of branches/plant under a row spacing of 45 cm as compared to 30 cm and 60 cm. The results further indicated that wider spacing beyond 45 cm did not increase the number of branches/plant. Tripathi *et al.* (2013) [82] observed highest number of secondary branches/plant (17.06) under the influence of wider spacing (45 × 20 cm). Similar to the above findings Ram and Singh (2011) [58] reported that closer row spacing of 22.5 cm produced lesser number of branches over 45 cm row spacing in sunnhemp.

Biomass production of sunnhemp was increased with increasing density and reached higher at seed rate of 100 kg/ha (Hiremath and Patel, 1995) [28]. In contrary to the above findings Tripathi *et al.* (2013) [82] reported that the wider spacing of 45 cm × 20 cm produced highest dry matter accumulation/plant (73.11 g) which was significantly superior to other spacing treatments and lowest DMP was recorded with a spacing of 30 cm × 10 cm (45.94 g). Though the above result seems to be differed from the above findings that the per plant DMP was more under wider spacing, by virtue of lower density per unit area, the DMP per unit area would be certainly lesser under wider spacing.

Yield attributes and yield

Higher number of pods/plant, more number of seeds/pod was produced under wider spacing (60 cm x 20 cm) than closer spacings (30 x 20 cm and 45 x 20 cm) in sunnhemp (Thomas and Palaniappan, 1998b) [80]. Similarly Ulemale *et al.* (2002) [84] observed higher number of pods/plant, higher number of seeds/pod and increase in 100 seed weight at 60 cm and 45 cm row spacings as compared to 30 cm row spacing in sunnhemp. Similar to number of branches/plant, more number of pods/plant, higher number of seeds/plant (27.85 g) and higher 100 seed weight were observed in 45 cm row spacing as compared to 30 cm spacing (Lamani *et al.*, 2010) [39]. Shastri *et al.* (2010) [70] reported higher number of pods/plant, higher number of seeds/pod at 45 cm x 20 cm spacing than 45 cm x 10 cm, 30 cm x 20 cm and 30 cm x 10 cm in sunnhemp, which revealed the importance of inter row spacing. Ram and Singh (2011) [58] also reported similar results that the number of pods/plant was higher under wider row spacing as compared to closer row spacing of 22.5 cm. Tripathi *et al.* (2013) [82] observed that number of pods/plant (78.44) was higher under wider spacing of 45 cm × 20 cm. The enhancement in number of pods/plant under the influence of wider spacing might be on account of maximum number of secondary branches/plant.

Higher number of seeds/pod and higher 100 seed weight were produced at 45 cm row spacing over 30 cm and 60 cm row spacing in sunnhemp (Deshpande *et al.*, 2000) [17]. However Tripathi *et al.* (2013) [82] reported that there was no significant difference in test weight due to different spacings (30 cm x 10 cm, 30 cm x 20 cm, 45 cm x 10 cm and 45 cm x 20 cm).

Higher seed yield in sunnhemp under close row spacing (30 cm) was reported by Solunke (1994) [73] and Malewar (1993) [43]. Significantly higher seed yield of sunnhemp was observed at narrow inter row spacing of 30 cm (28.5 q/ha); however, the seed yield/plant was higher at wider row spacing of 60 cm (30.3 q/ha) (Ekshinge *et al.*, 1995) [20]. Similarly Ulemale and Shivankar (2003) [85] reported significantly higher seed yield of 1091 kg/ha under closer row spacing of 30 cm as compared to wider row spacing of 45 cm (1007 kg/ha) and 60 cm (918 kg/ha) in sunnhemp at Akola. Shastri *et al.* (2010) [70] reported higher seed yield (2153 kg/ha), higher stalk yield at 30 cm x 10 cm spacing as compared to 45 cm x 10 cm (1716 kg/ha), 45 cm x 20 cm (1334 kg/ha) and 30 cm x 20 cm (1597 kg/ha) in sunnhemp. Tripathi *et al.* (2013) [82] also reported that higher seed yield (15.27 q/ha) and stalk yield (78 q/ha) was obtained from closer spacing of 30 cm x 10 cm when compared to wider spacing of 45 cm x 15 cm.

The above results differed with Biradar *et al.*, (1991) [5] as seed yield of sunnhemp was significantly higher by 16 per cent at wider row spacing of 45 cm over narrow row spacing of 30 cm. Thomas and Palaniappan (1998b) [80] reported higher seed yield at a wider spacing of 60 cm x 20 cm followed by 45 cm x 20 cm and 30 cm x 20 cm in sunnhemp. Similarly Deshpande *et al.* (2000) [17] noticed higher seed yield of 1095 kg/ha at 45 cm row spacing as compared to 30 cm row spacing (834 kg/ha) and 60 cm row spacing (957 kg/ha) in sunnhemp. Lamani *et al.* (2010) [39] reported that the seed yield of sunnhemp was highest with a row spacing of 45 cm (1094 kg/ha) than 30 cm (915 kg/ha) and 60 cm (1071 kg/ha). Ram and Singh (2011) [58] noticed that closer row spacing of 22.5 cm produced lesser seed yield (1151 kg/ha) compared to 45 cm (1165 kg/ha) row spacing in sunnhemp at Ludhiana.

The variation in fibre yield of sunnhemp was significant due to different planting geometry. Costa (1968) [12] reported significantly higher fibre yield of *Crotalaria juncea* when sown at 40 cm row spacing. Dargon (1974) [13] observed significantly higher fibre weight of sunnhemp in 40 cm row to row spacing as compared to 25 cm and 30 cm. Sowing of sunnhemp at the spacing of 15 cm x 10 cm produced significantly higher fibre yield (10.15 q/ha) over normal broadcast method. The fibre yield obtained with the spacing of 20 cm x 10 cm was on par with the spacing of 15 cm x 10 cm. The lowest fibre yield was noted under broadcast method. Sowing of crop in rows (15 cm x 10 cm) gave 25.8 % more fibre yield. The higher fibre yield associated with spacing of 15 cm x 10 cm might be attributed to higher plant population and green biomass (Tripathi *et al.*, 2013) [82].

Nutrient Management

Major nutrients like nitrogen (N), phosphorus (P) and potassium (K) play an important role on vegetative and reproductive phase of crop growth. Nitrogen (N) is an integral component of many compounds, including chlorophyll and enzymes, essential for plant growth processes. It is an essential component of amino acids and related proteins. Like all leguminous crops, sunnhemp is often not supplied with any nitrogenous fertilizers. However, for the initial boosting up the crop, 20 kg/ha nitrogen may be supplied. Nitrogen is essential for carbohydrates use within plants and stimulates root growth and development as well as the uptake of other nutrients (Sarkar *et al.*, 2015) [65].

Phosphorus is considered to be an important nutrient for legume crop, which results in large *rhizobium* population occurring in cultivated soil. Several attempts were made to assess the best form in which phosphates can be applied to crops (Thimmanna *et al.*, 2014) [78]. Phosphate increases the amount of nitrogen fixation. Phosphorus at 20 kg P_2O_5/ha is recommended for sunnhemp (Maitra *et al.*, 2008; Tripathi *et al.*, 2009) [42, 83]. Potassium fertilizer is applied to sunnhemp normally at 40 kg K_2O/ha. The response from the combination of P and K (P_{20} K_{40}) produced the highest yield (10.6 q/ha) of sunnhemp fibre at CRIJAF (Chaudhury *et al.*, 1997.; Saha *et al.*, 2009) [10, 61]. A high rate of potassium uptake was observed all throughout the growth period. Potassium levels of soil were shown to have a reflection on the occurrence of *rhizobium* (Sarkar *et al.*, 2015) [65].

Influences of nutrients on growth attributes in sunnhemp

Higher dry matter yield at P levels of 45 kg P_2O_5/ha in sunnhemp and beyond 45 kg P_2O_5/ha it did not show any significant differences (Mahajan and Khanna, 1968) [41]. Application of potash decreased the height, base diameter and fibre yield, whereas, phosphorus was found to have opposite effect (Iruthayaraj *et al.*, 1981) [31]. Application of 40 kg P_2O_5/ha gave the higher fibre yield and profit in sunnhemp. Sharma and Mittra (1988) [69] reported that sunnhemp produced higher dry matter accumulation when fertilized with 15 kg N + 30 kg P_2O_5 ha^{-1} than application of 15 kg N alone or no fertilization. Bodkhe and Shelke (1996) [6] reported that application of 50 kg N and 50 kg P_2O_5 significantly influenced growth attributes such as plant height, number of leaves, leaf area, number of branches and dry matter production/plant over no fertilization in sunnhemp.

Application of 50 kg P_2O_5/ha significantly increased the dry matter production of sunnhemp than other treatments with 0 kg and 25 kg P_2O_5/ha (Thomas and Palaniappan, 1998b) [80]. Tripathi *et al.* (2009) [83] observed that application of 15:30:15 kg N, P_2O_5, K_2O/ha produced taller plants of sunnhemp (231 cm), which was on par with 20:40:20 kg N, P_2O_5, K_2O/ha. Tripathi *et al.* (2012) [81] reported that application of nitrogen (20 kg/ha) showed significant increase in plant height, basal diameter, green weight and fibre yield over control. However, no significant difference was recorded between 20 and 40 kg nitrogen/hectare in sunnhemp.

Influences of nutrients on yield attributes and yield in sunnhemp

More number of pods/plant, higher number of seeds/pod and higher 100 seed weight at higher dose of phosphorus application than lower dose of phosphorus application in sunnhemp at Akola (Ulemale *et al.*, 2002) [84]. Kumar *et al.* (2010) [37] reported more number of pods/plant (69.6), number of seeds/pod and higher test weight (49.87 g) with a fertilizer dose of 37.5:75:37.5 kg N P_2O_5 K_2O/ha as compared to medium fertilizer level of 25:50:25 kg N P_2O_5 K_2O/ha.

Application of 25 kg N and 50 kg P_2O_5/ha recorded the higher seed yield of sunnhemp. Ulemale *et al.* (2002) [84] reported that higher seed yield of 594 kg/ha was obtained with application of phosphorus of 75 kg/ha as compared to phosphorus levels with 50 kg (562 kg/ha) and 25 kg/ha (523 kg/ha) in sunnhemp (Deshmukh *et al.*, 1997) [16]. Kumar *et al.* (2010) [37] reported that higher fertilizer level of 37.5:75:37.5 kg N P_2O_5 K_2O/ha produced significantly higher seed yield of 1562 kg/ha and higher stalk yield of 8680 kg/ha as compared to no or medium fertilizer level (25:50:25 kg N P_2O_5 K_2O/ha) in sunnhemp.

Sunnhemp responded to phosphorus up to 20 kg P_2O_5/ha. Further increase in the phosphorus to 40 kg/ha did not improve the fibre yield of sunnhemp to a significant level (Chaudhury *et al.*, 1995) [9]. However Maitra *et al.* (2008) [42] observed that fertilizer phosphorus significantly increased the fibre yield of sunnhemp up to 40 kg P_2O_5/ha and further increase in phosphorus level up to 60 kg P_2O_5/ha remained at par. The extents of increase in fibre yield of sunnhemp by application of 40 kg P_2O_5/ha were 14.69 per cent over no phosphorus. Application of nitrogen showed significant increase in fibre yield. However, no significant difference was recorded between application of 20 and 40 kg nitrogen/hectare. Higher fibre yield of 6.66 q/ha of was produced with nitrogen level of 20 kg/ha (Tripathi *et al.*, 2012) [81].

NPK Content and uptake

A significant increase in nitrogen accumulation with application of higher phosphorus level (50 kg P_2O_5/ha) as compared to application of lower phosphorus levels in sunnhemp was observed by (Thomas and Palaniappan 1998a) [79]. Kumar *et al.* (2010) [37] reported that higher uptake of nitrogen (151.7 kg/ha), phosphorus (35.7 kg/ha) and potassium (93.1 kg/ha) was resulted with higher fertilizer level of 37.5:75:37.5 kg N P_2O_5 K_2O/ha as compared to no or medium fertilizer level (25:50:25: kg N P_2O_5 K_2O/ha) in sunnhemp. Mitra *et al.* (2008) observed that total nitrogen, phosphorus and potassium uptake by sunnhemp was increased significantly with phosphorus application up to the higher level of 60 kg P_2O_5/ha as compared to 40kg P_2O_5/ha.

Halepyati and Sheelavantar (1991) [27] reported that application of phosphorus (150 kg/ha) increased the nitrogen accumulation (265.13 kg/ha) as compared to no phosphorus application (201.61 kg/ha) in *Sesbania rostrata*. Application of higher levels (50 kg P_2O_5/ha) increased the nitrogen and phosphorus accumulation in dhaincha as compared to lower levels of phosphorus (0 kg and 25 kg/ha) application (Parlawar *et al*., 2003).

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