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# Castor [Ricinus communis (L.)] - Sorghum [Sorghum bicolor (L.)] Cropping System Productivity, Soil Chemical and Biological Fertility in Response to Conservation Agriculture and Nutrient Management Practices in Alfisols

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**ABSTRACT:** A fixed plot experiment was conducted in Alfisols for three years from 2010 to 2012 at Narkhoda farm of Directorate of Oilseeds Research, Hyderabad. The main objective of the study was to know the effect of conservation agriculture (minimum tillage, crop residue and cover crop) and nutrient management practices (recommended dose of fertilizers, integrated nutrient management, organic nutrient management, fertilizers based on soil test crop response and customized fertilizers) on the productivity, nutrient uptake and soil chemical and biological fertility in castor – sorghum cropping system under rainfed conditions. Conservation agriculture was found to be on par with conventional agriculture with reference to system productivity, system nutrient uptake and soil chemical and biological fertility. Among nutrient management practices, fertilizer application based on soil test crop response (STCR) significantly improved the system productivity (2717 kg/ha), system nutrient uptake (188-62-198 N:$P_2O_5$:$K_2O$ kg/ha) and soil nutrient availability (224-30-430 N:$P_2O_5$:$K_2O$ kg/ha) which was on par with customized fertilizer. The productivity improvement with these set of treatments was 15% higher compared to that of recommended dose of fertilizer (RDF). Soil respiration (290 mg kg/d), microbial biomass C (320 mg/kg) and N (48.5 mg/kg) were significantly increased with organic nutrient management followed by integrated nutrient management.

**Key words**: castor, conservation agricultural practices, STCR, nutrient management, soil biological activity, sorghum

Castor, an important industrial oilseed crop of India accounts for 60% area and 68% production of world castor. The current castor production in the country is 19.64 lakh t harvested from 12.34 lakh ha with a productivity of 1592 kg/ha. In Telangana, it is grown in an area of 79,833 ha and producing 56,480 t of castor seed. The crop productivity in Telangana, is comparatively low (707 kg/ha). One of the important reasons for low productivity of castor is its cultivation in marginal and sub-marginal lands having poor soil quality i.e., shallow depth, low in organic matter content and poor fertility. These soils are susceptible to soil erosion and retain less moisture resulting in frequent drought-like conditions leading to poor crop productivity. Sorghum is a staple cereal grown in both rainy and post-rainy seasons in the semi-arid and arid parts of India on marginal and low fertile soils. In Alfisols of Telangana, castor-sorghum is the popular rotation and is grown in rainy season.

Conservation agricultural practices viz., minimum tillage, crop residue management and cover crops play an important role in bringing favourable changes in physical, chemical and biological properties, which in turn improve crop yields (Ramesh and Hegde, 2010). Site specific nutrient management (SSNM) practices namely, fertilizers based on soil test crop response (STCR) equations (Subba Rao and Srivastava, 2002) and recent developments in the crop-specific customized fertilizers are drawing attention to improve fertilizer recommendations for sustainable crop production. Customized fertilizers can maximize nutrient use efficiency and then improve soil fertility. Hence, they are considered as environmental friendly fertilizers (Nagendra Rao and Rahman, 2011).

As such double cropping is not feasible in light textured Alfisols of semi-arid tracts of southern India, but growing short duration legume like horsegram (Macrotyloma uniflorum) and cluster bean (Cyamopsis tetragonoloba) in sequence after sorghum and castor utilizing the residual moisture and off season rainfall in a good rainfall year can be a viable option for increasing the cropping intensity.

Keeping these facts in view, the present investigation was carried out to study the effect of conservation agriculture and nutrient management practices on the castor-sorghum cropping system productivity, nutrient uptake and soil chemical and biological fertility in Alfisols under rainfed conditions.

## Materials and Methods

A fixed-plot field experiment was conducted during kharif from 2010 to 2012 for three years at research farm of the Directorate of Oilseeds Research, Hyderbad, Telangana on Alfisols under rainfed conditions. The eco-region was characterized as semi-arid tropical (SAT) climate and soil has been classified as red sandy loam with pH 6.3, E.C 0.35 ds/m, low in organic carbon (0.35%) and available nitrogen (210 kg/ha), medium in available phosphorus (22.0 kg/ha) and high in potassium (420 kg/ha) at the initiation of experiment. Castor and sorghum were grown in 2010 in two separate blocks with crop specific treatments. In the castor block, sorghum was sown in 2011 and castor was grown in 2012. Similarly in the sorghum block, castor was grown in 2011 and sorghum was grown in 2012. Castor hybrid 'DCH-519' and sorghum hybrid 'RSH-99' were sown during the first week of July and harvested during October (for sorghum) and January (for castor) in each year.

The treatments include two production systems viz., conservation agricultural practices [minimum tillage, crop residue as mulch and cover crops (cluster bean in castor and horse-gram after sorghum)] and conventional agricultural practices (farmers' practice *viz.,* deep ploughing every year, 2 times with mould board plough and 2 times with cultivator) in main plots. The sub-plots include six nutrient management practices viz., recommended dose of fertilizers (RDF), integrated nutrient management (INM), organic nutrient management (ONM), fertilizers based on soil test crop response (STCR), customized fertilizers (CF) and the control. The STCR equations followed in the study are given in Table 1 (http://www.iiss.nic.in/downloads/STCR%20 2014.pdf). The treatments were replicated thrice in split-plot design. The details of nutrient management practices and their nutrient contribution were given in Table 2.

**Table 1 : STCR equations used in the experiment**

| Crop | Equation | Target yield (kg/ha) |
|---|---|---|
| Castor | F N = 8.35 T – 0.40 S N<br>F $P_2O_5$ = 7.17 T – 2.88 S P<br>F $K_2O$ = 3.02 T – 0.10 S K | 1500 |
| Sorghum | F N = 4.86 T – 0.53 S N<br>F $P_2O_5$ = 1.63 T – 0.87 S P<br>F $K_2O$ = 4.56 T – 0.59 S K | 4000 |

**Table 2 : Nutrient management practices and their nutrient contribution**

| S. No. | Nutrient management practice | Castor | Sorghum |
|---|---|---|---|
| 1 | Recommended dose of fertilizers (RDF) | 60-40-30* | 60-30-30* |
| 2 | Integrated nutrient management (75% RDF + 25% N through FYM) (INM) | 60-36-37* | 60-28-37* |
| 3 | Organic nutrient management (75% N through FYM and 25% N through poultry manure) (ONM) | 60-28-55* | 60-28-55* |
| 4 | Fertilizers based on soil test crop response (STCR) | 62-64-20* | 110-52-20* |
| 5 | Customized fertilizer (CF) | 65-50-37-17-5** | 113-52-48-4*** |
| 6 | Control | Nil | Nil |

* Kg N, $P_2O_5$ and $K_2O$/ha; ** Kg N, $P_2O_5$, $K_2O$, S and Zn/ha; *** Kg N, $P_2O_5$, $K_2O$ and Zn/ha

In chemical fertilizer treatments, half the dose of nitrogen and full dose of phosphorus and potassium was applied as basal dose at the time of sowing. The remaining half of the dose of nitrogen was top dressed in 2 splits a ¼ at 30 days and at 60 days after seeding in both the crops. In ONM and INM, FYM was applied a week before sowing; and in ONM, composted poultry manure was applied at 30 days after sowing for both the crops. The N:P:K content (%) of FYM and poultry manure on dry weight basis were 0.51: 0.12: 0.38 and 4.6: 1.06: 2.48, respectively. In INM treatment, 3 t FYM/ha was applied on dry weight basis in each crop. In ONM treatment, 9 t FYM/ha and 33 kg poultry manure/ha on dry weight basis in each crop were applied. The amount of manure was calculated based on percentage of recommended N to be met (25% or 75% recommended N of respective crops). Sorghum crop was sown at 45 x 10 cm spacing, while castor was sown at 90 x 60 cm spacing. The main-plot size was 42 x 8.0 m and sub-plot size was 7.2 x 6.6 m.

In conservation agricultural treatment, cluster bean as cover crop was sown between the rows of castor. The green pods of the cluster bean as vegetable were harvested at 60 DAS. The crop residue of both cluster bean and castor (after harvest) were retained as mulch on the soil surface. Whereas after harvest of sorghum, horsegram was sown as cover crop with the available residual soil moisture and the crop was left for decomposition in the field.

The total rainfall received during the crop season (July-December) was 975, 553 and 745 mm in 2010, 2011 and 2012, respectively against the average annual rainfall of 730 mm. The seed yield of sorghum and cluster bean were converted into castor equivalent yield which was calculated as under.

Castor equivalent yield (kg/ha) = Yield of sorghum/cluster bean (kg/ha) x Price of sorghum/cluster bean (₹/kg)/ Price of castor (₹/kg).

After harvest, treatment-wise seed and straw/stalk samples were collected for N, P and K nutrient analysis to calculate system nutrient uptake. Nitrogen was determined by micro Kjeldahl method, phosphorus was estimated by vanadomolybdate yellow colour method and potassium was determined with flame photometer method. At the end of the three years cropping cycle, the soil samples (0-15 cm) were collected for estimation of chemical and biological properties. Soil available N, P and K were estimated by adopting standard analytical methods (Singh et al., 2005). Microbial biomass C (MB-C) and N (MB-N) were estimated by using chloroform fumigation incubation method as described in Horwath & Paul (1994). Soil respiration was estimated according to the method of Anderson (1982). Statistical analysis of the data was carried out using standard analysis of variance. Pooled analysis was carried out with respect to castor equivalent yield and system nutrient uptake. Split plot analysis of the data and combined analysis with respect to castor equivalent yield and system nutrient uptake was carried out using SAS 9.3 (SAS Institute, Cary NC).

## Results and Discussion

In general, the productivity of castor/sorghum was low in 2010 due to heavy rains (975 mm) received during the crop season (July-December), which resulted in excessive vegetative growth followed by severe incidence of Botrytis grey rot in castor and poor seed setting in sorghum. In contrast, the crop yields were higher in 2011 and 2012 due to the optimum and well distributed rainfall of 553 mm and 745 mm, respectively from July-December and without any biotic limitations.

### System productivity, economics and nutrient uptake

Among the production systems, conservation agriculture recorded higher castor equivalent yield of 2327 kg/ha compared to conventional agriculture (2243 kg/ha), however the improvement is not statistically significant (Table 3). The improvement was mainly due to the contribution of additional gain from cluster bean pods (800 kg/ha) in conservation agriculture. Among the nutrient management practices, STCR based fertilizer application recorded significantly higher castor equivalent yield (2717 kg/ha) compared to RDF (2280 kg/ha) but was on par with that of CF (2703 kg/ha). It indicated that STCR method of fertilizer application improved the castor equivalent yield by 13%, 19% and 29% compared to INM, RDF and ONM, respectively. Higher productivity of castor and sorghum in the system with STCR (Raghavaiah et al., 2008) was due to favourable crop growth and higher yield attributes. In this treatment, nutrients were applied in proportion to the magnitude of deficiency of a particular nutrient and the correction of nutrient imbalances in soil that would have helped in harnessing the synergistic effects of balanced fertilization. Choosing the right yield targets and application of appropriate nutrients help in sustaining the soil fertility and crop yields (Subba Rao and Srivastava 2002).

Considerable differences were not observed between conservation agriculture and conventional agriculture practices with respect to system economics. The B:C ratio was higher with conventional agriculture (2.8) compared with conservation agriculture because of lower cost of cultivation in conventional agriculture (₹ 28,500/ha) than conservation agriculture (₹ 31,250/ha). Among nutrient management practices, net returns were greater with STCR (₹ 64,095/ha) followed by customized fertilizers (₹ 63,455/ha). The B:C ratio was not much differed between STCR (3.1) and customized fertilizers (3.0) (Table 4).

System nutrient uptake with conservation agriculture (159.3-53.3-170 kg NPK/ha) was statistically on par with that of conventional agriculture (160.7-50.2-169 kg NPK/ha). Among the nutrient management practices, STCR based fertilizer application recorded greater uptake of nutrients (188.1-61.9-197.9 kg NPK/ha) compared to RDF (155-52.6-165 kg NPK/ha) but, it was on par with that of CF (184.4-59.9-191.8 kg NPK/ha) (Table 3).

**Table 3 : Castor equivalent yield (mean of three years) and nutrient uptake (at the end of 3 years cropping cycle) as influenced by conservational and nutrient management practices**

| Treatment | Castor equivalent yield (kg/ha) | System nutrient uptake (kg/ha) | | |
|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ |
| Production systems | | | | |
| Conservation agriculture | 2327 | 159.3 | 53.3 | 170.0 |
| Conventional agriculture | 2243 | 160.7 | 50.2 | 169.0 |
| SEm± | | | | |
| CD (P=0.05) | NS | NS | NS | NS |
| Nutrient management | | | | |
| Recommended dose of fertilizers (RDF) | 2280 | 155.0 | 52.6 | 165.0 |
| Integrated nutrient management (INM) | 2383 | 169.3 | 50.7 | 170.5 |
| Organic nutrient management (ONM) | 2100 | 143.6 | 50.8 | 162.3 |
| Fertilizers based on soil test crop response (STCR) | 2717 | 188.1 | 61.9 | 197.9 |
| Customized fertilizers (CF) | 2703 | 184.4 | 59.9 | 191.8 |
| Control | 1537 | 119.7 | 33.1 | 128.5 |
| SEm± | | | | |
| CD (P=0.05) | 350 | 29 | 4.5 | 27 |
| Interaction | NS | NS | NS | NS |
| C.V (%) | 14 | 14 | 13 | 16 |

**Table 4 : Castor-sorghum system economic returns accrued as influenced by conservational and nutrient management practices (mean of three years)**

| Treatment | Gross returns (₹/ha) | Cost of cultivation (₹/ha) | Net returns (₹/ha) | B:C ratio |
|---|---|---|---|---|
| Production systems | | | | |
| Conservation agriculture | 81445 | 31,250 | 50,195 | 2.6 |
| Conventional agriculture | 78505 | 28,500 | 50,005 | 2.8 |
| Nutrient management | | | | |
| Recommended dose of fertilizers (RDF) | 79800 | 28,300 | 51,500 | 2.8 |
| Integrated nutrient management (INM) | 83405 | 31,400 | 52,005 | 2.7 |
| Organic nutrient management (ONM) | 73500 | 33,700 | 39,800 | 2.2 |
| Fertilizers based on soil test crop response (STCR) | 95095 | 31,000 | 64,095 | 3.1 |
| Customized fertilizers (CF) | 94605 | 31,150 | 63,455 | 3.0 |
| Control | 53795 | 23,700 | 30,095 | 2.3 |

Sale price (₹/kg): Castor 35; sorghum 10; sorghum stover 0.25; clusterbean pods 6
Manure/Fertilizer cost (₹/kg): urea 5.6; SSP 6.6; MoP 14.4; FYM 0.5; Poultry manure 0.5; customized fertilizer for castor 13; customized fertilizer for sorghum 9.25

## Soil fertility

Soil respiration (228 kg/kg 10 $d^{-1}$), microbial biomass C (255 mg/kg) and N (38.6 mg/kg) with conservation agriculture system was on par with that of conventional agriculture (208; 235; 35.6). Addition of cover crops and crop residues resulted in improvement of soil biological activity under conservation agriculture production system compared to conventional agriculture; however the differences were not statistically significant. In the long run there is a scope for significant improvement under conservation agriculture (Sharma et al., 2005). ONM improved the soil biological activity viz., soil respiration (290 mg/kg 10 $d^{-1}$), microbial biomass C (320 mg/kg) and N (48.5 mg/kg) which was on par with INM. Complete inorganic source of fertilizer application viz., STCR, CF, RDF treatments recorded lesser biological activity than that of ONM and INM treatments. Control plots recorded the lowest levels of soil respiration (170 kg/kg 10 $d^{-1}$), microbial biomass C (214 mg/kg) and N (32.4 mg/kg) (Table 5). Higher levels of microbial biomass C and N in organic manure treated plots could be due to greater amounts of biogenic materials like mineralizable nitrogen, water soluble carbon and carbohydrates. Integrated use of chemical fertilizers and organic matter brings in more microbial biomass C and N soil compared to their single application (Khosro Mohammadi, 2012).

Improvement in soil available N (217 kg/ha), P (27.9 kg/ha) and K (424 kg/ha) with conservation agriculture system could be due to the addition of biomass through cluster bean (in castor) and horsegram (as cover crop after sorghum) along with the decomposition of castor crop residues applied as mulch compared to that of conventional agriculture where crop residues were not added (213; 26.7; 420 N:P:K kg/ha), though differences were not significant. Among the nutrient management practices, STCR (224:30:430 N:P:K kg/ha), CF (222:29.7:429 N:P:K kg/ha) and ONM (221:29.8:428 N:P:K kg/ha) recorded higher soil available N: P: K status compared to control plot (191: 19.3:410 N:P:K kg/ha) (Table 5). Intensive tillage in conventional system must have caused decline in organic matter content through accelerated oxidation, resulting in reduced capacity of the soil to regulate water and nutrient supplies to plants. When crop residues are retained on the soil surface in combination with minimum tillage, it initiates process of conservation that leads to improved soil quality and overall resource enhancement (Bhale and Wanjari, 2009). Ramesh et al. (2010) also reported that application of organic manures over a period of time improves the soil organic matter content and soil fertility, thereby sustaining soil health and crop productivity.

## Conclusions

In Alfisols under rainfed conditions, conservation agricultural practice (minimum tillage, cover crops and residue management) can be followed without any adverse effect on total productivity of castor-sorghum cropping system besides sustaining the soil chemical and biological fertility. STCR based fertilizer application resulted in improved system productivity, soil nutrient availability compared to RDF.

**Table 5 : Soil biological and chemical properties as influenced by conservational and nutrient management practices at the end of three years cropping cycle (mean values of castor and sorghum blocks)**

| Treatment | Soil biological properties | | | Soil available nutrients (kg/ha) | | |
|---|---|---|---|---|---|---|
| | Soil respiration (mg/kg 10 $d^{-1}$) | Microbial biomass C (mg/kg) | Microbial biomass N (mg/kg) | N | $P_2O_5$ | $K_2O$ |
| Production system | | | | | | |
| Conservation agriculture | 228 | 255 | 38.6 | 217 | 27.9 | 424 |
| Conventional tillage | 208 | 235 | 35.6 | 213 | 26.7 | 420 |
| SEm± | 8 | 11 | 4.5 | 5.2 | 3.7 | 5.2 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| Nutrient management | | | | | | |
| Recommended dose of fertilizers (RDF) | 200 | 225 | 34.1 | 210 | 27.2 | 420 |
| Integrated nutrient management (INM) | 250 | 265 | 40.2 | 216 | 27.8 | 415 |
| Organic nutrient management (ONM) | 290 | 320 | 48.5 | 221 | 29.8 | 428 |
| Fertilizers based on soil test crop response (STCR) | 200 | 225 | 34.1 | 224 | 30.0 | 430 |
| Customized fertilizers (CF) | 195 | 220 | 33.3 | 222 | 29.7 | 429 |
| Control | 170 | 214 | 32.4 | 191 | 19.3 | 410 |
| SEm± | 24.6 | 23.2 | 3.2 | 3.0 | 1.3 | 5.8 |
| CD (P=0.05) | 75 | 70 | 10 | 9 | 3.8 | 18 |
| Interaction | NS | NS | NS | NS | NS | NS |
| C.V (%) | 15 | 16 | 14 | 12 | 10 | 10 |

Soil biological activity was improved with ONM and INM. Improvement of soil health is essential to sustain system productivity in the long term. Therefore, STCR based INM practice for castor-sorghum system needs to be developed for the twin benefit of improving soil chemical and biological fertility and seed yield.

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