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Plant growth, yield, quality and nutrient content of grain cowpea in relation to tillage levels and nutrient management practices

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Abstract
Sustainable agricultural practices can improve soil properties, growth and yield of crops. A field experiment of split plot design was conducted to study the effect of tillage and nutrient management on growth, yield and quality attributes of grain cowpea**.** The main plot treatments were tillage levels such as conventional tillage (m_1), deep tillage (m_2) and no till (m_3). The sub plot treatments were different nutrient management practices like KAU POP recommendation (s_1), soil test based POP (s_2), organic nutrient management using TOF-F (s_3), POP + AMF (s_4), soil test based POP + AMF (s_5), TOF-F+ AMF (s_6) and absolute control (s_7). The highest plant height (1.83 m), shoot weight (171.23 g), no of pods plant^{-1} (55.44), grain yield plant^{-1} (107.70 g), total dry matter plant^{-1} (180.71 g) and crude protein (13.63%) were recorded by the nutrient management s_5. The highest root weight (25.21 g), active nodule number (50.78) and root volume (12.22 cm^3) were observed by s_6. Among the tillage levels, m_3 performed best in connection with growth, yield and quality characteristics. Among nutrient management s_5 remained superior for plant height, shoot biomass and grain yield plant^{-1} and s_6 exhibited higher values for root characteristics and quality parameters.

Keywords: Tillage, nutrient management, organic manure, grain cowpea, grain yield, root biomass, shoot biomass

Introduction

Grain cowpea (*Vigna unguiculata* (L.) Walp.) is an important food legume which is adapted to wide range of soils, rainfall situations and fits as a niche crop in multiple and intercropping systems. It is the most versatile pulse crop because of its smoothening nature, drought tolerance and multiple uses such as green vegetable, nitrogen fixation, food legumes to tackle malnutrition as it is rich in proteins and vitamins and is also used as hay, silage, pasture, fodder, soil cover and green manure (Hakim *et al.*, 2022) [10].

The faulty agricultural management practices like excessive tillage, continuous use of inorganic fertilizers, herbicides, and fungicides, burning of crop residues etc. had resulted in various problems to soil and reduction in plant growth and yield (Yang *et al.*, 2004; Meena *et al.*, 2021) [34, 21]. Tillage plays an important role in maintaining physical as well chemical properties of soil and ultimately affecting the crop productivity. Tillage serves as an effective way to modify the properties of soil because of its effect on density, pore space, residue cover and surface roughness (Liu *et al.*, 2021: Phohlo *et al.*, 2022) [19, 26]. According to Yang and Wander (1999) [35] the use of reduced and no-tillage practices increases the SOC concentration in surface soil and proportion of stable aggregates in the upper surface of soil. It has been also found that NT not only increase aggregate stability but also improves SOM inside the aggregates. Shukla *et al.* (2003) [37] reported higher infiltration rates under no tillage than conventional tillage because of the protection of the soil surface and effects of soil organic matter.

Organic manures can improve soil properties by decreasing bulk density, increasing water holding capacity, aggregate stability, saturated hydraulic conductivity, water infiltration rate and biochemical activities, leading to a slow release of available nutrients through OM decomposition, resulting in better plant growth and yield (Allam *et al.*, 2022; Ma *et al.*, 2021) [2, 20]. Organic manures and compost applications had resulted in higher SOC content compared to same amount of inorganic fertilizers applications (Choudhary *et al.*, 2022; Turner *et al.*, 2007) [6, 31].

Many studies revealed that inoculation of AMF increased the availability of various macro and micro nutrients significantly, which leads to an increased photosynthate production and thus resulting in an increased biomass accumulation (Chen *et al.*, 2017; Mitra *et al.*, 2019) [5, 22].
Besides that AMF has the capability to stimulate the uptake of inorganic nutrients in plants, particularly of phosphate ions (Nell *et al.*, 2010) [23]. AMF are more active in nutrient-deficient soils and assists plants for effective nutrient mining (Kayama and Yamanaka, 2014) [17].
Besides that AMF can improve the nutritional quality of many crops by increasing the levels of production of carotenoids and certain volatile compounds (Hart *et al.*, 2015) [11]. Bona *et al.* (2017) [4] observed the beneficial effects of AMF in improving quality of tomatoes. In a study by Zeng *et al.* (2014) [36] enhancement in citrus fruit quality was noted due to an increased concentration of sugars, organic acids, vitamin C, flavonoids, and minerals by AMF - *Glomus versiforme.* Enhanced accumulation of anthocyanins, chlorophyll, carotenoids, total soluble phenolics, tocopherols, and various mineral nutrients in association with mycorrhizal symbiosis was reported by Baslam *et al.* (2011) [3].
Agricultural practices for more carbon sequestration like conservation tillage practices (reduced tillage and no till), cover cropping with legumes having well developed root systems in addition to N fixation capacity, retention of crop residues in fields etc. have to be adopted to ensure long term soil quality and sustainability. Better fertility management through proper soil testing, precision farming, integrated nutrient management involving combinations of bio fertilizers, organic manures and chemical fertilizers etc. can also ensure better crop yields without having deleterious effect on soil quality and the ecosystem.

2. Materials and Methods

Field experiment was carried out at the Instructional Farm, College of Agriculture, Vellayani with grain cowpea variety Kanakamony from January 2020 to March 2020. The experimental site is situated at 8˚ 25′ 46″ North latitude and 76˚ 59′ 24″ East longitude, at an altitude of 29 m above MSL. The soil of the experimental site was classified as loamy, kaolinitic isohyperthermic Typic Kandiustults of Vellayani series. The experimental design used was of split plot design with four replications. The main plot treatments were three tillage levels such as m_1: Conventional tillage, m_2: Deep tillage (30 cm depth), m_3: No till. The sub plot treatments were different nutrient management practices like s_1: KAU Package of Practices (POP) Recommendation, s_2: Soil test based POP, s_3: Organic nutrient management (thermochemical fortified organic fertilizer (TOF-F), s_4: POP + AMF, s_5: Soil test based POP + AMF, s_6: Organic nutrient management (TOF-F) + AMF, s_7: Absolute control.
The field was treated with glyphosate @ 0.8 kg active ingredient ha^{-1} prior to field preparation. The main plots (14.7 m x 1.5 m) and sub plots (2.1 m x 1.5 m) were laid out after thorough ploughing in conventional and deep tilled treatments and with a minimum disturbance in no tilled plots. A distance of 30 cm was maintained between sub plots and main plots (Fig 1). Lime was applied @ 350 kg ha^{-1} and after two weeks of lime application basal dose of FYM (20 t ha^{-1}) was also provided as per POP recommendation for grain cowpea (KAU, 2016) [16].
Seeds of grain cowpea, variety Kanakamony obtained from ORARS, Kayamkulam were treated with *Rhizobium* culture, shade dried and dibbled immediately by maintaining a spacing of 25 cm between rows and 15 cm between plants @ two seeds per hole.
POP recommendation (KAU, 2016) [16] was followed for sub plot treatments s_1 and s_4, soil test based POP recommendation for s_2 and s_5 and thermo chemical fortified organic manure (TOF-F) for s_3 and s_6. The fertilizer recommendations as per POP, N (20 kg ha^{-1}), P_2O_5 (30 kg ha^{-1}) and K_2O (10 kg ha^{-1}) were applied where half dose of N and whole P and K was applied as basal and remaining nitrogen was applied 15-20 days after sowing. The soil test based POP recommendations for s_2 and s_5 were 84 per cent of general recommendation for N and 25 per cent for P and K.
The fortified thermochemical organic fertilizer (TOF-F) popularized as Suchitha was prepared as per standard method (Sudharmaidevi *et al.*, 2017) [30]. The organic manure, TOF-F was applied in terms nitrogen equivalence ie. 1.33 t ha^{-1} for s_3 and s_6 where half of the dose as basal and remaining half after 15 days of sowing. The AMF was applied @ 5 g plant^{-1} along with dibbled seed for treatments s_4, s_5 and s_6.
The growth and yield characters were recorded from the tagged observational plants for each treatment avoiding the border plants. The pods were harvested at mature stage, dried in shade and labelled separately as per treatments. After the final harvest, observational plants were pulled out and dried to record the dry matter. The plant samples were oven dried at 70 ºC and powdered for analysis as per standard methods; C content by weight loss on ignition CHNS Analyzer (Vario EI cube, Elementar, Germany) - Nelson and Sommers (1996); N content by Micro kjeldahl digestion in H_2SO_4 followed by distillation - Jackson (1973) [12]; P content by nitric-perchloric (9:4) acid digestion and spectrophotometry using vanado-molybdo yellow colour method (Double Beam UVVIS spectrophotometer 2201, Systronics) - Jackson (1973) [12]; and Crude protein content (Simpson *et al.*, 1965) [29].
The data generated from the field experiment were analyzed statistically by applying the analysis of variance technique for split plot design using KAU GRAPES software (Gopinath, 2021) [8]. The significance between treatments were tested by comparing CD values for main plots, sub plots and their interaction effects with the respective table values and the significance were tested at 5 per cent level.

3. Results and Discussion

3.1 Growth, yield and quality parameters

Among the various nutrient managements, soil test based POP + AMF (s_5) recorded the highest plant height (1.83 m) and shoot biomass (171.23 g) of grain cowpea. The treatment TOF-F + AMF (s_6) followed it in shoot biomass and showed highest value for root characteristics like root volume (12.22 cm^3), root weight (25.21 g) and number of active nodules (50.78) (Table 1). In both the cases the positive influence of AMF was very much evident since the same treatments without AMF did not show the same trend.
In legumes, P stimulated nodulation, N fixation and plant growth was reported by Vance, (2001) [32]. The AMF symbiosis is particularly effective for the enhanced uptake of immobile nutrients, especially phosphorus which is needed for proper root growth and nodulation which might have resulted in better growth and yield attributes in treatments with AMF.

Evaluating the role of TOF-F on plant growth, its prominent role on root growth was observed. Similar results with TOF-F, highly favouring root growth was reported by Jacob (2018) [13] and Ramesha, (2019) [27] in maize and amaranthus respectively. The soil test based POP was found to be more efficient in total dry matter production plant^{-1} (180.71 g) and grain yield plant^{-1} (107.70 g) when applied along with AMF (Table 2). In the absence of AMF, TOF-F had more favorable influence on growth characteristics while on yield and yield attributes it was not reflected. Though the TOF-F was applied based on the N basis, the amount of other essential nutrients present in it might not be able to meet the demand in accordance with the root biomass production mainly due to the recalcitrant nature of TOF-F (Sudharmaidevi *et al.*, 2017; Ramesha 2019; Ajayan, 2021; Leno *et al.*, 2021) [30, 27, 1, 18]. Somehow, it might have failed the translocation of nutrients to above ground parts and utilization for photosynthate production.

The combination of AMF with soil test based POP (s_5) and organic nutrient management TOF-F (s_6) remained superior to POP+ AMF (s_4) combination as the excessive mineral fertilization had an inhibitory effect on AMF activity while controlled fertilization and organic manured treatments promotes AMF colonization and activity (Gryndler *et al.*, 2001; Johnson *et al.*, 2003) [9, 15].

Among the tillage levels, the no till treatment (m_3) performed best in connection with growth and yield characteristics. No tilled condition which might have facilitated decaying of plant residues in the site itself increasing SOM accumulation and it might have been helpful for enhanced growth and yield attributes. Besides that no till condition can result in better soil structure development leading to better aeration and absorption of nutrients and water reflecting in higher growth and yield characteristics (Nunes *et al.*, 2020) [25].

The interaction effects on various growth and yield attributes were also significant showing a same replica of treatments for both main and sub plot treatments.ie. no till – s_5 and no till- s_6 combinations were superior. In case of no till, a minimum disturbance to soil occurs which does not disrupt the AMF hyphal network leading to better nutrient acquisition, protection of soil organic C by facilitating macro-aggregate formation etc. leading to better growth and yield rates (Galvez *et al.*, 2001; Jansa *et al.*, 2003) [7, 14].

Regarding the crude protein of grain cowpea of different treatments, the soil test based POP along with AMF (13.63%) recorded highest values and all the AMF combinations had better quality parameter than their respective treatments (Table 2). The roots along with extensive hyphal network of AMF can explore vast surface area to meet up balanced nutritional requirements reflecting in the improved quality parameter. The ability of AMF to improve the quality of fruit crops and vegetables by increasing the accumulation of minerals, flavonoids, anthocyanins, carotenes, vitamins etc were already reported (Baslam *et al.*, 2011; Hart *et al.*, 2015) [3, 11]. The no till treatment (m_3) performed best in connection with crude protein (12.86%) of grain cowpea. Interaction effect of m_3s_5 combination remained superior due to the balanced nutrition made possible by mineral fertilizers along with profound AMF activity under controlled fertilization (Galvez *et al.*, 2001; Jansa *et al.*, 2003; Sekaran *et al.*, 2020) [7, 14, 28].

Table 1: Effect of tillage and nutrient management on growth characteristics of grain cowpea

Treatments	Plant height (m)	Shoot weight (g plant^{-1})	Root weight (g plant^{-1})	No of active nodules	Root volume (cm^3)	Days to 50% flowering
Main plot						
m_1	1.68^b	137.14^b	17.98^b	33.48^b	7.29^b	29.67^a
m_2	1.28^c	127.80^c	16.38^c	27.00^a	6.52^c	29.00^b
m_3	1.89^a	156.34^a	20.53^a	42.95^a	7.91^a	29.43^{ab}
SEm±	0.02	0.96	0.96	0.44	0.07	0.12
CD (0.05)	0.06	3.78	3.78	1.72	0.26	0.47
Sub plot						
s_1	1.64^d	130.61^c	19.69^d	34.00^d	5.44^e	28.89^c
s_2	1.49^f	123.52^e	14.17^e	30.10^e	4.78^f	29.78^b
s_3	1.54^e	126.71^d	13.30^f	24.33^f	6.22^d	29.78^b
s_4	1.76^b	157.27^b	22.51^b	39.11^c	7.78^c	27.78^d
s_5	1.83^a	171.23^a	21.67^c	48.11^b	9.89^b	28.78^c
s_6	1.72^c	158.00^b	25.21^a	50.78^a	12.22^a	27.7^d
s_7	1.33^g	115.66^f	11.52^g	14.89^g	4.33^g	32.78^a
SEm±	0.01	1.00	1.00	0.43	0.13	0.19
CD (0.05)	0.03	2.87	2.87	1.22	0.37	0.55
Interactions						
m_1						
s_1	1.85	122.55	20.90	32.33	5.67	30.33
s_2	1.58	117.18	13.02	29.00	4.67	30.67
s_3	1.77	115.42	12.93	24.00	6.33	29.67
s_4	1.73	158.67	22.40	43.00	7.67	28.00
s_5	1.79	173.90	20.68	45.33	10.00	29.00
s_6	1.64	158.92	24.66	45.67	12.00	27.33
s_7	1.39	113.34	11.24	15.00	4.67	32.67
m_2						
s_1	1.26	111.60	17.10	31.33	4.33	27.00
s_2	1.16	107.38	11.83	29.00	4.33	28.00
s_3	1.23	114.00	12.35	22.67	5.67	30.33
s_4	1.41	145.08	21.39	28.00	7.33	28.00

s_5	1.48	164.35	18.47	32.33	9.33	28.67
s_6	1.39	140.85	24.09	32.67	11.00	28.00
s_7	1.04	111.31	9.43	13.00	3.67	33.00
m_3						
s_1	1.81	157.67	21.08	38.33	6.33	29.33
s_2	1.72	146.01	17.67	32.33	5.33	30.67
s_3	1.63	150.70	14.61	26.33	6.67	29.33
s_4	2.15	168.05	23.75	46.33	8.33	27.33
s_5	2.21	175.43	25.85	66.67	10.33	28.67
s_6	2.13	174.21	26.87	74.00	13.67	28.00
s_7	1.58	122.32	13.90	16.67	4.67	32.67
SEm±	0.02	1.74	1.74	0.74	0.23	0.33
CD (0.05)	0.05	4.98	4.98	2.12	0.65	0.96

m_1: Conventional tillage; m_2: Deep tillage; m_3: No till; s_1: POP; s_2: Soil test based POP; s_3: TOF-F; s_4: POP+AMF; s_5: Soil test based POP+AMF; s_6: TOF-F+AMF; s_7: Absolute control

Table 2: Effect of tillage and nutrient management on yield and quality characteristics of grain cowpea

Treatments	Pod weight (g)	No of seeds pod^{-1}	100 seed weight (g)	Grain yield plant^{-1} (g)	Dry matter production plant^{-1}	Crude protein (%)
Main plot						
m_1	2.01^{b}	14.19^{b}	11.01^{b}	77.16^{b}	133.31^{b}	12.47^{b}
m_2	1.99b	13.76^{c}	9.40^{c}	62.63c	125.21^{c}	12.19^{c}
m_3	2.34a	15.33^{a}	11.65^{a}	91.56^{a}	154.03^{a}	12.86^{a}
SEm±	0.10	0.11	0.07	0.76	0.33	0.03
CD (0.05)	0.37	0.39	0.26	2.97	1.28	0.14
Sub plot						
s_1	2.31^{b}	14.22^{b}	10.86^{c}	72.20^{d}	135.26^{d}	12.55^{c}
s_2	2.25^{c}	14.22^{b}	10.94b^{c}	71.55^{d}	129.81^{e}	12.09d
s_3	2.02^{e}	15.11^{a}	10.82^{c}	62.23^{e}	107.44^{e}	11.93^{e}
s_4	2.39^{a}	13.78^{c}	11.31^{a}	92.95^{c}	174.12^{c}	13.20^{b}
s_5	2.21^{c}	15.22^{a}	11.06^{b}	107.70^{a}	180.71^{a}	13.63^{a}
s_6	2.08^{d}	15.33^{a}	10.94^{bc}	95.82^{b}	154.01^{b}	12.66^{c}
s_7	1.55^{f}	13.11^{d}	8.88^{d}	37.37^{f}	81.24^{f}	11.49^{f}
SEm±	0.14	0.13	0.07	0.84	0.35	0.05
CD (0.05)	0.41	0.40	0.20	2.42	1.00	0.15
Interactions						
m_1						
s_1	2.17	14.00	11.30	72.92	131.29	12.73
s_2	2.11	14.00	11.72	70.31	117.13	12.02
s_3	2.04	15.67	10.90	64.83	104.45	11.79
s_4	2.21	13.00	11.29	82.22	161.88	13.17
s_5	2.28	14.33	11.47	103.21	186.81	13.63
s_6	2.01	15.33	11.33	105.89	156.23	12.44
s_7	1.28	13.00	9.08	40.71	75.35	11.50
m_2						
s_1	2.14	13.33	9.90	68.31	127.06	12.10
s_2	2.04	13.67	9.19	51.01	104.45	11.65
s_3	1.99	15.33	9.60	49.13	98.26	11.77
s_4	2.13	13.00	9.30	74.22	162.83	12.89
s_5	2.07	15.67	10.06	99.23	165.94	13.21
s_6	2.01	14.00	9.45	66.64	137.26	12.34
s_7	1.57	11.33	8.30	29.88	80.70	11.37
m_3						
s_1	2.63	15.33	11.37	75.36	147.44	12.81
s_2	2.60	15.00	11.91	93.33	167.85	12.58
s_3	2.02	14.33	11.96	72.74	119.62	12.23
s_4	2.84	15.33	13.34	122.41	197.64	13.54
s_5	2.29	15.67	11.64	120.64	189.38	14.05
s_6	2.21	16.67	12.05	114.93	168.62	13.21
s_7	1.80	15.00	9.27	41.51	87.67	11.59
SEm±	0.25	0.23	0.12	1.46	0.60	0.09
CD (0.05)	0.71	0.69	0.34	4.20	1.73	0.26

m_1: Conventional tillage; m_2: Deep tillage; m_3: No till; s_1: POP; s_2: Soil test based POP; s_3: TOF-F; s_4: POP+AMF; s_5: Soil test based POP+AMF; s_6: TOF-F+AMF; s_7: Absolute control

3.2 Nutrient concentration of shoot and root biomass

The carbon and nitrogen content of grain cowpea followed a different trend from that of growth and yield characteristics. The treatment POP + AMF (s_4) maintained highest C content in shoot (52.36%) and soil test based POP + AMF (s_5) in root (50.05%) of grain cowpea (Table 3). For nitrogen content of grain cowpea a reverse order with that of carbon content was noted. The shoot nitrogen content of grain cowpea was highest for the treatment soil test based POP + AMF (2.18%) and the root N content was highest for POP + AMF (1.43%). The N assimilation by grain cowpea was further affected by atmospheric fixation of N and this might have influenced carbon assimilation also (Wang *et al.*, 2021) [33].

Regarding the levels of tillage a varied behavior from that of growth and yield attributes were observed. The conventional tillage (m_1) gave highest C content in both shoot (46.29%) and root (48.43%) of grain cowpea. The N content of shoot (2.06%) was highest for no till (m_3) while root N (1.25%) was highest for deep tillage (m_2). Deep till might have promoted a temporary rise in soil microbial activity leading to more nutrient release from SOM that have facilitated better N uptake.

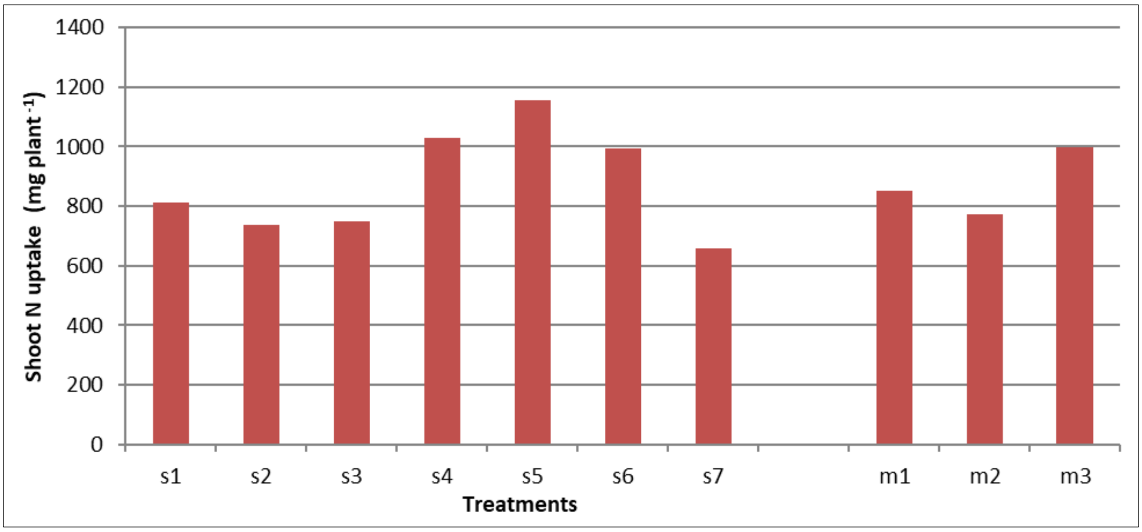
Regarding the P content of grain cowpea, among the nutrient levels, TOF-F + AMF (s_6) had highest P content in both shoot (0.222%) and root (0.177%). The AMF included treatments had more P content and among them controlled fertilized and organic manured treatments were found to be superior due to enhanced AMF activity resulting in more nutrient absorption especially P from deeper soil layers through their extensive hyphal network. Among the tillage levels, no till was found to perform best as other tillage practices lead to disruption of hyphal networks affecting P acquisition.

In case of nutrient uptake by grain cowpea, the treatment s_5 (TOF-F + AMF) recorded highest shoot N uptake while s_4 recorded highest root N uptake and for P ie. both shoot and root P uptake were higher for s_6 (TOF-F + AMF) (Fig 1 to Fig 4). Among tillage levels, no till (m_3) remained superior for both N and P uptake. The balanced nutrition along with action of AMF might have resulted in higher nutrient uptake for the treatment s_5 and better physical condition and enhanced microbial activity under no tilled condition had resulted in higher nutrient uptake.

Table 3: Effect of tillage and nutrient management on nutrient concentration of grain cowpea

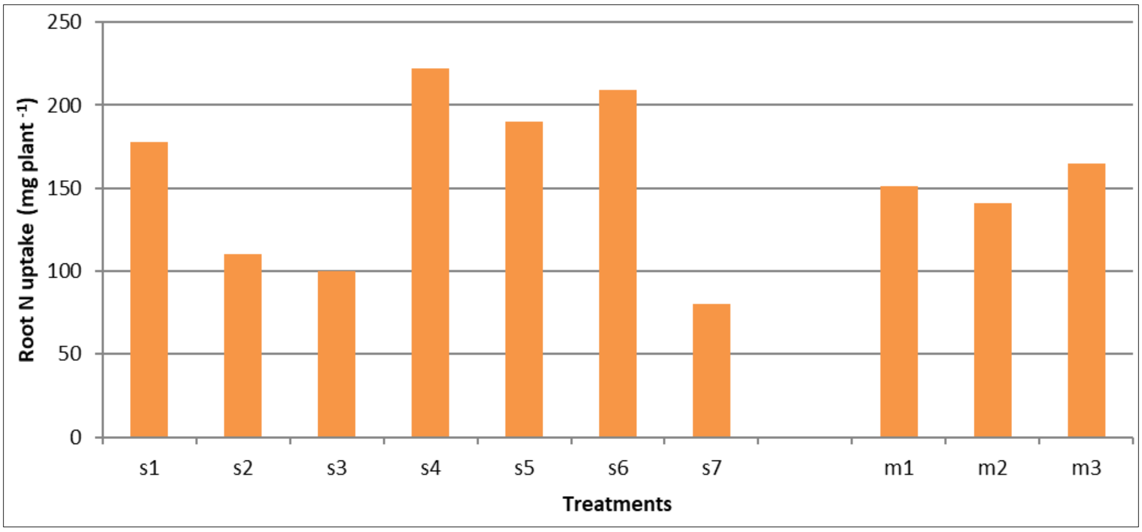
Treatments	Shoot C (%)	Root C (%)	Shoot N (%)	Root N (%)	Shoot P (%)	Root P (%)
Main plot						
m_1	46.29	48.43	2.00^b	1.22^b	0.181^b	0.135^a
m_2	45.91	48.04	1.95^c	1.25^c	0.179^b	0.130^b
m_3	46.01	47.86	2.06^a	1.17^a	0.187^a	0.137^a
SEm±	-	-	0.01	0.004	0.001	0.001
CD (0.05)	NS	NS	0.02	0.016	0.003	0.004
Sub plot						
s_1	44.87	46.82	2.01^c	1.27^b	0.168^e	0.096^e
s_2	44.86	46.66	1.93^d	1.10^c	0.173^d	0.116^d
s_3	44.60	47.63	1.91^e	1.09^d	0.179^c	0.153^b
s_4	52.36	48.38	2.11^b	1.43^a	0.181^c	0.132^c
s_5	45.29	50.05	2.18^a	1.27^b	0.198^b	0.172^a
s_6	46.08	49.96	2.03^c	1.20^b	0.222^a	0.177^a
s_7	44.44	47.27	1.84^f	1.00^e	0.156^f	0.092^e
SEm±	-	-	0.01	0.008	0.002	0.002
CD (0.05)	NS	NS	0.24	0.024	0.005	0.005
Interactions						
m_1						
s_1	46.24	48.25	2.04	1.31	0.173	0.097
s_2	45.20	47.01	1.92	1.17	0.173	0.117
s_3	44.35	47.37	1.89	1.09	0.180	0.153
s_4	52.81	48.80	2.11	1.44	0.180	0.133
s_5	45.29	50.69	2.18	1.29	0.187	0.177
s_6	45.66	49.54	1.99	1.25	0.220	0.173
s_7	44.50	47.35	1.84	1.00	0.157	0.093
m_2						
s_1	43.74	45.64	1.94	1.27	0.163	0.09
s_2	44.16	45.93	1.86	1.18	0.170	0.11
s_3	45.55	48.66	1.88	1.16	0.183	0.153
s_4	52.54	48.55	2.06	1.48	0.180	0.13
s_5	44.40	49.72	2.11	1.31	0.183	0.167
s_6	46.24	50.17	1.97	1.31	0.220	0.173
s_7	44.75	47.61	1.82	1.04	0.153	0.09
m_3						
s_1	44.64	46.58	2.05	1.23	0.167	0.100
s_2	45.22	47.03	2.01	1.13	0.177	0.120
s_3	43.89	46.87	1.96	1.04	0.173	0.153
s_4	51.72	47.78	2.17	1.37	0.183	0.133
s_5	46.18	49.73	2.25	1.22	0.223	0.173
s_6	46.33	50.19	2.11	1.21	0.227	0.183
s_7	44.05	46.86	1.85	0.96	0.157	0.093
SEm±	0.46	0.47	0.01	0.015	0.003	-
CD (0.05)	1.31	1.34	0.04	0.042	0.008	NS

m_1: Conventional tillage; m_2: Deep tillage; m_3: No till; s_1: POP; s_2: Soil test based POP; s_3: TOF-F; s_4: POP+AMF; s_5: Soil test based POP+AMF; s_6: TOF-F+AMF; s_7: Absolute control



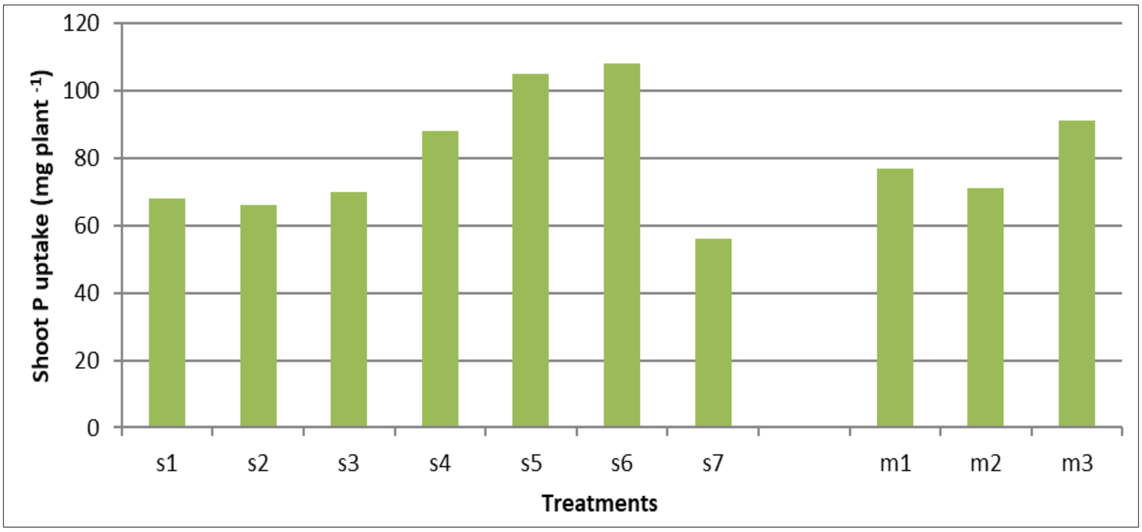
m_1: Conventional tillage; m_2: Deep tillage; m_3: No till; s_1: POP; s_2: Soil test based POP; s_3: TOF-F; s_4: POP+AMF; s_5: Soil test based POP+AMF; s_6: TOF-F+AMF; s_7: Absolute control

Fig 1: Shoot N uptake of grain cowpea as affected by nutrient management and tillage



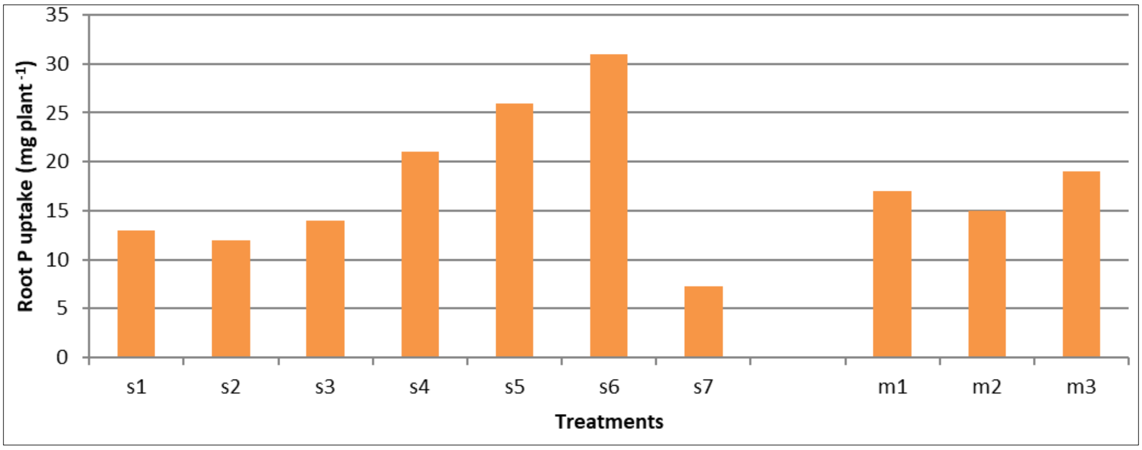
m_1: Conventional tillage; m_2: Deep tillage; m_3: No till; s_1: POP; s_2: Soil test based POP; s_3: TOF-F; s_4: POP+AMF; s_5: Soil test based POP+AMF; s_6: TOF-F+AMF; s_7: Absolute control

Fig 2: Root N uptake of grain cowpea as affected by nutrient management and tillage



m_1: Conventional tillage; m_2: Deep tillage; m_3: No till; s_1: POP; s_2: Soil test based POP; s_3: TOF-F; s_4: POP+AMF; s_5: Soil test based POP+AMF; s_6: TOF-F+AMF; s_7: Absolute control

Fig 3: Shoot P uptake of grain cowpea as affected by nutrient management and tillage



m_1: Conventional tillage; m_2: Deep tillage; m_3: No till; s_1: POP; s_2: Soil test based POP; s_3: TOF-F; s_4: POP+AMF; s_5: Soil test based POP+AMF; s_6: TOF-F+AMF; s_7: Absolute control

Fig 4: Root P uptake of grain cowpea as affected by nutrient management and tillage

Conclusion

The different nutrient management and tillage levels significantly influenced growth, yield, quality and nutrient concentration of grain cowpea. The AMF included treatments performed best when compared to their respective without AMF treatments. The importance of soil test based fertilizer recommendation and use of organic manures and biofertilizers in sustaining growth, yield and other attributes were highlighted in the study. Among the tillage levels, no till treatment exhibited better growth, yield and quality parameters reflecting the need of the adoption of minimum soil disturbance practices in farming to conserve soil and to gain sustainable yields from crops.

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Declaration

The authors declare that they have no conflict of interests concerning the current research publication

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