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The impact of long-term manure and balanced fertilisation on yield and yield attributes of groundnut, wheat and sorghum on *Vertic haplustepts* under groundnut-wheat-sorghum cropping system

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Abstract
The study has been carried out for showing of yields and yield attributes in a groundnut-wheat-sorghum (fodder) cropping system under a permanent plot experiment (2000-2020) in medium black calcareous soil at the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh. There were six treatments, *viz*., T_1: control, T_2: FYM @ 25 t/ha, T_3: ½ NP, T_4: ½ NP + K, T_5: NP and T_6: NP + K. The recommended fertilizer doses for groundnut, wheat and sorghum are 12.5-25-50, 120-60-60 and 80-40-00, respectively. The pooled results of groundnut yield indicated that the half dose of N and P recommended for the respective crops under irrigated condition but with K (T_3) increased pod and haulm yield in first 10 years, while, with increasing level of fertilizer application (T_6: Full dose of N and P recommended for the respective crops under irrigated condition but with K) increased pod and haulm yield of groundnut in next 10 years. However, increasing level of fertilizer application significantly increased grain and straw yield of wheat and fodder yield of sorghum in groundnut-wheat-sorghum cropping system in medium black calcareous soil of PPE over 20 years, whereas maximum value was found under the treatment of full dose of N and P recommended for the respective crops under irrigated condition but with K (T_6). The result revealed that application of inorganic fertilizer improved soil fertility and produces a maximum yield of groundnut, wheat and sorghum in groundnut-wheat-sorghum cropping system.

Keywords: Permeant plot experiment (PPE), organic and inorganic fertilizers, yields and yield attributes

Introduction

The green revolution, probably the greatest achievement in agriculture gave a tremendous boost to agricultural production resulting from India having self-sufficiency in food production riding on the use of chemical fertilizers. The continuous and inadequate use of imbalanced fertilizer leads to deterioration in soil chemical, physical, biological properties and soil health (Mahajan *et al.*, 2008) [7] and multi-nutrient deficiency emerged with time in many areas. Soil health are continued decline during the past some decades is one of the most consequential problem in India which causing not only recession in food grain production but also unsafe for nutritional and economic security.

Crop production potential is influenced mostly by soil quality. The physical, chemical and biological aspects of the soil can all be used to determine its quality. These characteristics are vital not only for the soil's function as a growing medium for plants, but also for its role as a buffer in the development and elimination of dangerous chemicals (Larson and Pierce, 1994) [5]. Furthermore, improving the physical, chemical, and biological aspects of soil, which are effective markers of quality change, is necessary for maintaining and improving soil quality (Doran, 1996) [2]. Soil quality refers to the combined influence of management on the majority of soil parameters that determine agricultural yield and sustainability. Good soil quality not only produces good agricultural yields, but it also protects the environment and, as a result, the health of plants, animals and humans. Soil fertility has been deteriorating as a result of crops being grown without regard for total nutrient requirements (Ghosh *et al*., 2003) [3]. Soil quality evaluation has been proposed as a technique for assessing the long-term viability of soil and crop management practices (Hussain *et al*., 1999) [4].

The use of higher doses of fertilizer in the absence of organic manuring is sure to have an impact on soil fertility. Long-Term Fertilizer Experiments (LTFE) are the finest technique for determining the impact of fertilizers and manure on soil sustainability.

Long-term fertilizer trials are a great source of information about fractionation of soil organic matter. The first of its kind in the world was founded at Rothamsted, England, in 1843. Long-term manurial experiments were first established in India in 1885. Following that, experiments were started in Pusa (1908) and Coimbatore (1909). Long term fertilizer experiments involving intensive cereal-based cropping systems reveal a declining trend in productivity even with the application of recommended levels of N, P and K fertilizers (Mahajan *et al*., 2002; Mahajan and Sharma, 2005) [8, 6].

Materials and Methods

A permeant plot experiment (PPE) was established in 1979 on a *Vertic haplustepts* of the instructional farm of Junagadh Agricultural University, Junagadh, Gujarat, India in order to study the potash status of soil as affected by intensive cropping under medium and high fertility levels with and without applied potash (In collaboration with Agronomy department, J. A. U., Junagadh).

Experimental soil

The parent material of this residual soil is basaltic trap. The profile of these soils morphologically exhibits an A-C horizon with a moderate sub-angular blocky structure. The soil's colour ranges from dark grey to light grey. The soil is categorized as *Haplustepts* in taxonomic terms. This soil is dominated by the smectite group of clay minerals, which causes minor cracking during the dry season, therefore, it is classified as *Vertic haplustepts* at the subgroup level. The soil is clayey in texture. Data on initial soil characteristics (0-15 cm depth) measured at the onset of the cropping cycle during 2079-80 revealed that the soil was alkaline in reaction (pH 8.50) and non-saline (EC 0.19 dS/m) and contained 0.65% organic matter, 0.083% total N, 28.16 kg/ha available (0.05 *M* $NaHCO_3$-extractable) P_2O_5, 272.0 kg/ha available (1*N* ammonium acetate extractable) K_2O.

Treatments and crop management practices

This experiment comprises 12 treatments that include chemical fertilizers alone or in combination with organic sources such as farmyard manure (FYM) and an unfertilized control. The treatments are being studied in a randomized block design with four replications on a permanent (undisturbed) layout as shown in Table 1. However, in the current study, 6 out of the total 12 treatments and 4 replications were included in current experiment, as shown in Table 2.

Table 1: Experimental details

1	Crop	Groundnut (GG 11) Wheat (GW 496) Sorghum (Local Gundari)
2	Year of commencement	*Kharif,* 1979-80
3	Seed rate (kg/ha)	Groundnut (80 kg/ha) Wheat (100 kg/ha) Sorghum (80 kg/ha)
4	Experimental design	RBD (Randomized Block Design)
5	Plot size	Gross- 15.00 x 5.40 m Net- 12.00 x 4.20 m (For groundnut) 12.00 x 4.50 m (For wheat and sorghum)

Table 2: Details of experimental treatments

Sr. No.	Treatments	Details
T1	Control	Control
T2	25 t/ha FYM	Application of 25 t/ha FYM in *Kharif* 1979-82-85-88-91-94-97-00-03-06-09-12-15-18
T3	½ NP	Half dose of N and P recommended for the respective crops under irrigated condition but without K
T4	½ NP + K	Half dose of N and P recommended for the respective crops under irrigated condition but with K
T5	NP	Full dose of N and P recommended for the respective crops under irrigated condition but without K
T6	NP + K	Full dose of N and P recommended for the respective crops under irrigated condition but with K

Results

Yield of groundnut, wheat and sorghum crops

Groundnut pod yield

The pod yield of groundnut was significantly influenced by various treatments of experiment in pooled result over 20 years in medium black calcareous soil at JAU, Junagadh. The result of the pooled study from 2001-2010 was significant and revealing that the soils treated with ½ NP + K provided significantly higher groundnut pod yield (935 kg/ha) followed by T_6: NP + K (921 kg/ha) in groundnut-wheat-sorghum cropping system. Likewise, the pooled study from 2011-2020 also showed that significantly the highest pod yield (1331 kg/ha) was recorded under treatments receiving full dose of NP + K to groundnut-wheat-sorghum system. During the experiment, the interaction between year and treatment was also discovered to be significant (Table 3). The lowest pod yield was reported under control, with tune values of 470 and 481 kg/ha over 20 years.

Groundnut haulm yield

The haulm yield of groundnut was also considerably influenced by several experimental treatments in the pooled results with the highest haulm yield being observed under the half dose of NP + K treatment (2452 kg/ha) whereas, treatments T_6 remain at par with T_4 during 2001-2010. Furthermore, the pooled study from 2011-2020 also found to be significant and revealed that significantly the highest pod yield (2246 kg/ha) was recorded under treatments receiving full dose of NP + K to groundnut-wheat-sorghum system. Significantly the lowest haulm yield was obtained under control treated plot with values of 1219 and 902 kg/ha, respectively. The interaction between year and treatment was shown to be significant (Table 4).

Table 3: Groundnut pod yield as influenced by various treatments in groundnut-wheat-sorghum cropping system

Treatments	Groundnut pod yield (kg/ha)			
	Pooled (2001-2010)		Pooled (2011-2020)	
T_1: Control	470		481	
T_2: 25 t/ha FYM	569		1143	
T_3: ½ NP	531		826	
T_4: ½ NP + K	935		950	
T_5: NP	390		963	
T_6: NP + K	921		1331	
S.Em. ±	64.87		47.58	
C.D. at 5%	184		135	
C.V.%	11.89		10.73	
Y X T	S.Em. ±	37.84	S.Em. ±	50.95
	C.D. at 5%	105	C.D. at 5%	142

Wheat grain yield

The grain yield of wheat was significantly affected by various fertilization treatments of permanent plot experiments in groundnut-wheat-sorghum cropping system (Table 5). The treatment NP + K produced significantly the highest grain yields (3029 kg/ha) in pooled over 2001-2010. However, the pooled result from 2011-2020 showed that significantly the highest grain yield (3883 kg/ha) was recorded under the full dose of NP + K treatment in groundnut-wheat-sorghum cropping system. The interaction between year and treatment was also found to be significant in wheat grain yield during the experiment.

Table 4: Groundnut haulm yield as influenced by various treatments in groundnut-wheat-sorghum cropping system

Treatments	Groundnut haulm yield (kg/ha)			
	Pooled (2001-2010)		Pooled (2011-2020)	
T_1: Control	1219		902	
T_2: 25 t/ha FYM	1488		1928	
T_3: ½ NP	1798		1444	
T_4: ½ NP + K	2452		1587	
T_5: NP	1233		1639	
T_6: NP + K	2173		2246	
S.Em. ±	100.23		61.97	
C.D. at 5%	285		176	
C.V.%	9.70		12.39	
Y X T	S.Em. ±	83.77	S.Em. ±	100.68
	C.D. at 5%	234	C.D. at 5%	281

Table 5: Wheat grain yield as influenced by various treatments in groundnut-wheat-sorghum cropping system

Treatments	Wheat grain yield (kg/ha)			
	Pooled (2001-2010)		Pooled (2011-2020)	
T_1: Control	792		1570	
T_2: 25 t/ha FYM	1881		2741	
T_3: ½ NP	1580		2842	
T_4: ½ NP + K	2635		3122	
T_5: NP	1898		3391	
T_6: NP + K	3029		3883	
S.Em. ±	128.63		85.39	
C.D. at 5%	366		243	
C.V.%	14.44		11.67	
Y X T	S.Em. ±	142.24	S.Em. ±	170.69
	C.D. at 5%	397	C.D. at 5%	476

Wheat straw yield

The data in Table 6 shows wheat straw yield as a result of several treatments under the PPE in groundnut-wheat-sorghum cropping system. During the pooled analysis from 2001-2010, full doses of NP + K treatment resulted in significantly higher straw yields (3498 kg/ha) in groundnut-wheat-sorghum cropping system followed by T_4 (3188 kg/ha). However, pooled result by the next 10th year, the NP + K fertilizer treatment (5884 kg/ha) had a substantial impact on wheat straw production, but it was not statistically at par with rest of the treatments. The interaction of Y x T was found to be significant for wheat straw yield. Furthermore, the lowest straw yield of wheat was recorded under control (1302 and 2546 kg/ha, respectively) treatment.

Table 6: Wheat straw yield as influenced by various treatments in groundnut-wheat-sorghum cropping system

Treatments	Wheat straw yield (kg/ha)			
	Pooled (2001-2010)		Pooled (2011-2020)	
T_1: Control	1302		2546	
T_2: 25 t/ha FYM	2454		4108	
T_3: ½ NP	2233		4422	
T_4: ½ NP + K	3188		4926	
T_5: NP	2291		5279	
T_6: NP + K	3498		5884	
S.Em. ±	180.21		136.40	
C.D. at 5%	513		388	
C.V.%	12.29		10.20	
Y X T	S.Em. ±	153.32	S.Em. ±	230.93
	C.D. at 5%	428	C.D. at 5%	645

Sorghum fodder yield

In sorghum, fodder yield differed significantly due to various applications of fertilizers in the soils of permanent plot experiment (Table 7) in groundnut-wheat-sorghum cropping system. The results revealed that significantly the highest fodder yield was recorded with full dose of NP + K treatment with tune values of 14672 and 8196 kg/ha during 2001-2010 and 2011-2020, respectively. However, significantly the lowest fodder yield of sorghum was recorded in control with a tune figure of 2902 and 2830 kg/ha, respectively.

Table 7: Sorghum fodder yield as influenced by various treatments in groundnut-wheat-sorghum cropping system

Treatments	Sorghum fodder yield (kg/ha)			
	Pooled (2001-2010)		Pooled (2011-2020)	
T_1: Control	2902		2830	
T_2: 25 t/ha FYM	8631		5153	
T_3: ½ NP	8968		5782	
T_4: ½ NP + K	11624		6296	
T_5: NP	7674		7102	
T_6: NP + K	14672		8196	
S.Em. ±	732.37		216.17	
C.D. at 5%	2086		615	
C.V.%	11.20		10.31	
Y X T	S.Em. ±	508.23	S.Em. ±	303.78
	C.D. at 5%	1420	C.D. at 5%	848

Discussion

In a permanent plot experiment, the groundnut pod and haulm yield were increased by the continuous application of inorganics, i.e., a full dose of NP + K in groundnut-wheat-sorghum cropping system over 20 years. Although the year x treatment interactions were significant, the same treatment invariably recorded the highest value on a long-term basis, both for the pod and haulm yield of groundnut. The findings are supported by the work of Redda and Kebede (2017) [10]. A similar trend was also observed for grain and straw yields of wheat and fodder yields of sorghum. This indicated that a continual application of nitrogen fertilizers along with phosphorous and potassium had a significant effect on groundnut, wheat and sorghum in groundnut-wheat-sorghum cropping system over 20 years. The results corroborate the findings of Wang *et al.* (2010) [13] and Chauhan and Bhatnagar (2014) [1], who also reported that long-term integrated nutrient management trials in wheat on *vertisols* revealed the highest sustainability yield index (SYI). Similarly, Ravankar *et al.* (2004) [9] reported that the highest yield of wheat and the uptake of nutrients were recorded at 100 percent NPK with 10 t/ha FYM. Sihag *et al*. (2005) [11] was also studied that the combined application of organic and inorganic fertilizers in a continuous manner might have sustained the crop yield. The highest productivity of wheat was recorded in the treatment comprising 100% NPK + FYM in long term fertilizers experiment (Singh *et al.*, 2017) [12].

Conclusion

The application of inorganic fertilizers boosted the groundnut pod and haulm yield in groundnut-wheat-sorghum cropping system over 20 years in permanent plot experiment. On a long-term basis, the treatment NP + K consistently produced the highest pod and haulm yields of groundnut in groundnut-wheat-sorghum cropping system over 20 years.

Wheat grain and straw yields as well as sorghum fodder yields, showed comparable trends in groundnut-wheat-sorghum cropping system over 20 years. This suggests that regular application of inorganic fertilisers could have kept the crop production stable.

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