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Periodical changes in physico-chemical properties and macronutrient status of the soil under different cultivation practices and various crops in Alfisols of Konkan region

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Abstract
A field experiment was conducted during *Rabi* 2021-22 at the Research Farm of Department of Agronomy, College of Agriculture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri. A study on the effect of different cultivation practices and various crops on physico-chemical properties and macronutrient status of the soil was carried out. The experiment was laid out in split-plot design comprising 16 treatments which were replicated thrice. The treatments comprising of different cultivation practices *viz*, low budget farming, organic farming, conservation farming and conventional farming practices were undertaken in the main plot. The sub plot included groundnut, maize, brinjal and watermelon crops. The soil was collected periodically and analysed for different physico-chemical properties i.e. pH, electrical conductivity and organic carbon and macronutrient content i.e. for nitrogen, phosphorous and potassium content. The conservation farming practice recorded the highest content of physico-chemical properties and macronutrient content as compared to all the other cultivation practices at different growth stages of the crops. However, the electrical conductivity was the least under the conservation farming practice throughout the crop growth period. The data in respect of crops, revealed the highest soil pH under the brinjal crop, at different crop growth stages. At 30 DAS and 60 DAS, brinjal crop recorded the least value of electrical conductivity, at 90 DAS and at harvest, the least values of electrical conductivity were registered under brinjal and groundnut crops, respectively. The watermelon recorded the highest organic caron content at 30 DAS, maize registered the highest organic carbon content at 60 DAS, however, brinjal noted the highest organic carbon content at 90 DAS and at harvest of the crops. At all the stages of crop growth, groundnut recorded higher values of the available nitrogen and available phosphorous content in soil. However, the content of available potassium in soil was superior under the watermelon at all the stages of the crop growth.

Keywords: Different cultivation practices, physico-chemical properties, macronutrient status, groundnut, brinjal, maize, watermelon, Alfisols

Introduction
Cultivated groundnut (*Arachis hypogaea* L.) or peanut is a self-pollinated annual legume crop. In India, groundnut is grown on 4.77-million-hectare area with the production of 7.40 MT. Groundnut is the third major source of edible oil in India with a production of 8.94 MT in 2017-18. In Maharashtra state it is cultivated on an area of 0.33-million- hectare having 0.42 MT of production with a productivity of 1275 kg ha^{-1} (Anonymous 2019) [2]. In Konkan region, groundnut is grown on an about 20,000 ha area with 1.8 t ha^{-1} productivity (Waghmode *et al*. 2017) [27].

Maize is the third most important cereal crop next to wheat and rice in the world agriculture economy both as food for man and feed for animal. In India it is grown over an area of 8.49 million hectare with total production of about 21.28 MT and average yield of 2.024 tons per hectare (Anonymous, 2011) [3]. Sweet corn (*Zea mays saccharata*) also known as sugar corn is hybridized variety of maize (*Zea mays*), specifically bred to increase the sugar content.

Brinjal (*Solanum melongena Linn*.) belongs to the family Solanaceae. India is its centre of origin and diversity. In our country, brinjal cultivation shares the total production of about 8 percent and is cultivated on an area of 662.5 thousand hectare with total production of 12,515.2 thousand MT and average productivity of 18.9 MT ha^{-1}. While in Maharashtra, it is cultivated on an area of 21,090 hectare with total production of 407,640 MT and productivity of 19.33 MT ha^{-1} in 2015-16 (Anonymous, 2017) [1].

Watermelon belongs to the gourd family Cucurbitaceae and the genus Citrullus. Watermelon rind and seed also have many health benefits due to the presence of important amino acids citrulline, fibres, minerals, and phenolic compounds (Zubairu *et al*. 2018) [29]. India is often considered as secondary place of origin (Fursa 1973) [11]. The commercial cultivation of watermelon is possible in rice-based cropping system in Konkan region.

Low budget farming is a cultivating method for the natural development of yields without using substance composts. It is a unique chemical-free method that involves agro-ecology. It reduces farming expenses and promotes the use of natural fertilizers and local seeds. It uses biological pesticides for crop protection. Farmers can use cow dung, urine, human excreta, plants, natural fertilizers, and earthworms. It protects the soil from degradation and decreases the farmer's investment.

The USDA organic regulations describe organic agriculture as the application of a set of cultural, biological, and mechanical practices that support the cycling of on-farm resources, promote ecological balance and conserve biodiversity. These include maintaining or enhancing soil and water quality; conserving wetlands, woodlands and wildlife and avoiding the use of synthetic fertilizers, sewage sludge, irradiation, and genetic engineering

Conservation agriculture is based on the interrelated principles of minimal mechanical soil disturbance, permanent soil cover with living or dead plant material and crop diversification through rotation or intercropping. It helps farmers to maintain and boost yields and increase profits, while reversing land degradation, protecting the environment, and responding to growing challenges of climate change

Conventional farming refers to farming systems which include the use of synthetic chemical fertilizers, pesticides, herbicides and other continual inputs, genetically modified organisms, concentrated animal feeding operations, heavy irrigation, intensive tillage, and concentrated monoculture production. Cropping system, an important component of a farming system, represents a cropping pattern used on a farm and their interaction with farm resources, other farm enterprises and available technology, which determine their makeup.

The present study was undertaken to contemplate the performance of undertaken crops under different cultivation practices.

Material and Methods

The experiment was conducted during *Rabi* 2021-22 at Research Farm, Department of Agronomy, College of Agriculture, Dapoli., Dist. Ratnagiri in Maharashtra. The soils of experimental site were sandy clay loam in texture, slightly acidic in reaction with low electrical conductivity and high in organic carbon content. The soil was medium in available nitrogen, low in available phosphorus and high in available potassium content. Kaolinite is the dominant clay mineral in the soil.

The experiment was laid out in split-plot design comprising 16 treatments which were replicated thrice. The main plots consisted of low budget farming, organic farming, conservation farming and conventional farming practices. The sub plot comprised of various crops like groundnut, maize, brinjal and watermelon. The soil was collected periodically and analysed for different physico-chemical properties (*viz*., pH, electrical conductivity and organic carbon). The pH and electrical conductivity in soil were determined potentiometrically and conductometrically as per the procedure given by Jackson (1973) [13] while, the organic carbon was determined by Walkley and Black's wet digestion method as described by Black (1965) [6]. The available nitrogen was estimated by Subbiah and Asija (1956) [25], available phosphorous by Bray's No.1 method as described by Black (1965) [6] and the available potassium was determined by Neutral Normal Ammonium acetate extract by Flame photometry as given by Jackson (1973) [13]. The data obtained during investigation was subjected to statistical analysis by following the procedure pertinent to split-plot design, as given by Fisher (1971) [10].

Results and Discussion

Initial physico-chemical properties of the soil

The soil of the experimental plots consisting of low budget farming, organic farming, conservation farming and conventional farming practices (Table 1) was lateritic, moderately acidic (pH 5.40-5.45) in reaction and non-saline (EC 0.03 and 0.06 dS m^{-1}, respectively). It was very high in organic carbon (11.8-12.3 g kg^{-1}) content. The bulk density of the low budget farming, organic farming, conservation farming and conventional farming plots was 1.50, 1.51, 1.51 and 1.52 Mg m^{-3}, respectively, however, the particle density was 2.63, 2.62, 2.63 and 2.63 Mg m^{-3}, respectively. The texture of the soil was sandy clay loam having 49.34, 49.38, 40.26 and 49.32 percent sand, 22.45, 22.29, 22.21 and 22.23 percent silt and 28.21, 28.33, 28.23 and 28.45 percent clay, respectively. The available macronutrient *viz*., nitrogen, phosphorus and potassium contents were medium (243.6, 252.3, 254.2 and 249.1 kg N ha^{-1}), very low (10.50, 12.35, 11.50 and 11.55 kg P_2O_5 kg ha^{-1}) and moderately high (234.4, 241.5, 256.3 and 249.6 kg K_2O ha^{-1}), respectively. The DTPA extractable micronutrients *viz*., iron (45.30, 52.25, 54.49 and 50.65 mg kg^{-1}) manganese (19.98, 20.05, 22.37 and 21.13 mg kg^{-1}), zinc (3.45, 3.86, 3.90 and 3.68 mg kg^{-1}) and copper content (13.78, 15.32, 15.94 and 15.57 mg kg^{-1}) were well supplied in low budget farming, organic farming, conservation farming and conventional farming practice plots, respectively.

Table 1: Initial physico-chemical properties of the soil

S.no	Soil component analysed	Content			
		Low budget farming	Organic farming	Conservation farming	Conventional farming
A.)	**Physical properties**				
1.	Sand (%)	49.34	49.38	49.26	49.32
2.	Silt (%)	22.45	22.29	22.21	22.23
3.	Clay (%)	28.21	28.33	28.23	28.45
4.	Textural class	Sandy clay loam			
5.	Bulk density (Mg m^{-3})	1.50	1.51	1.51	1.52
6.	Particle density (Mg m^{-3})	2.63	2.62	2.63	2.63
7.	Porosity (%)	36.45	36.48	36.49	36.50
8.	Maximum water holding capacity (%)	42.25	43.50	44.50	44.00
B.)	**Chemical properties**				
1.	pH (1:2.5)	5.40	5.43	5.45	5.44
2.	Electrical conductivity (dS m^{-1})	0.06	0.05	0.03	0.04
3.	Organic carbon (g kg^{-1})	11.9	12.2	12.3	11.8
4.	Available nitrogen (kg ha^{-1})	243.6	252.3	254.2	249.1
5.	Available phosphorous (kg ha^{-1})	10.50	12.35	11.50	11.55
6.	Available potassium (kg ha-^{1})	234.4	241.5	256.3	249.6
7.	DTPA extractable Fe (mg kg^{-1})	45.30	52.25	54.49	50.65
8.	DTPA extractable Mn (mg kg^{-1})	19.98	20.05	22.37	21.13
9.	DTPA extractable Zn (mg kg^{-1})	3.45	3.86	3.90	3.68
10.	DTPA extractable Cu (mg kg^{-1})	13.78	15.32	15.94	15.57

Periodical changes in physico-chemical properties of the soil

pH (soil reaction)

Effect of cultivation practices

The data pertaining to the periodical changes in soil pH (Table 2) at different growth stages under different cultivation practices varied from 5.89 to 5.97 at 30 DAS, 5.93 to 6.01 at 60 DAS, 5.95 to 6.02 at 90 DAS and 5.95 to 6.03 at harvest of the crops.

Effect of crops

The data regarding periodical changes in soil pH as represented in Table 2, in respect of various crops indicated the non-significant effect. However, the pH of soil at different stages due to groundnut, maize, brinjal and watermelon varied from 5.88 to 5.98 at 30 DAS, 5.94 to 5.99 at 60 DAS, 5.96 to 6.00 at 90 DAS and 5.97 to 6.01 at harvest of the crops.

Numerically, highest pH was recorded under conservation farming practice and brinjal crop, as influenced by different cultivation practices and various crops, respectively. The data indicated that the soils are slightly to moderately acidic in nature. The acidic nature of soils might be attributed to leaching of soluble salts due to heavy precipitation in the Konkan region.

Table 2: Effect of different cultivation practices and various crops on periodical changes in the soil reaction (pH)

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Cultivation practices				
C_1: Low budget farming	5.89	5.93	5.95	5.95
C_2: Organic farming	5.94	5.95	5.97	5.97
C_3: Conservation farming	5.97	6.01	6.02	6.03
C_4: Conventional farming	5.93	5.98	5.99	6.00
SE (±)	0.02	0.02	0.02	0.02
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
Crops				
S_1: Groundnut	5.95	5.97	5.98	6.00
S_2: Maize	5.88	5.94	5.96	5.97
S_3: Brinjal	5.98	5.99	6.00	6.01
S_4: Watermelon	5.92	5.97	5.99	5.98
SE (±)	0.03	0.02	0.02	0.02
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
Interaction effect				
SE (±)	0.06	0.03	0.04	0.03
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
General mean	5.93	5.97	5.98	5.99

There was a slight increase in the soil pH from 30 DAS to harvest of groundnut, maize, brinjal, and watermelon crops during the experimental year. The increase in pH of acid soil was due to the addition of organic manures, which attributed the deactivation of Fe^{3+} and concomitant release of basic cations during their decomposition. Salvi *et al.* (2015) [21] also observed a significant increase in soil pH at 45 DAS and 120 DAS after application of organic manure along with chemical fertilizers and biofertilizers as compared to absolute control.

Electrical conductivity

Effect of cultivation practices

The electrical conductivity at different growth stages regarding different cultivation practices showed non-significant effect. The lowest values of electrical conductivity (0.08, 0.09, 0.07 and 0.09 dS m^{-1}) were noted in conservation farming practice and the highest values (0.11, 0.11, 0.10 and 0.11 dS m^{-1}) were registered in low budget cultivation practice at 30 DAS, 60 DAS, 90 DAS and at harvest, respectively (Table 3). The data obtained in respect of the cultivation practices indicated that the experimental soil exhibited least soluble salts. Electrical conductivity of acid soils found in Konkan region indicated that the soils are free of soluble salts, which might be attributed to the leaching of soluble salts due to heavy precipitation. The lateritic soils are devoid of soluble salts as reported by number of workers (Shende, 2010) [24]. There was a slight decrease in the electrical conductivity of soil from 60 to 90 DAS and then a slight increase in the electrical conductivity was observed from 90 DAS to harvest of the crops. The increase in electrical conductivity due to addition of FYM was attributed to the presence of salts in FYM (Saraswat *et al.* 2012) [23] and possible build-up of the soluble nutrients drawn from manure on mineralization. Increase in the electrical conductivity with organic manures was also reported by Diwale (2012) [9] for different soils.

Effect of crops

The electrical conductivity of soil at different stages due to various crops *viz,* groundnut, maize, brinjal and watermelon showed non-significant effect. However, it ranged from 0.08 to 0.11 dS m^{-1} at 30 DAS, 0.09 to 0.11 dS m^{-1} at 60 DAS, 0.08 to 0.10 dS m^{-1} at 90 DAS and 0.09 to 0.11 dS m^{-1} at harvest of the crops. Brinjal recorded the least electrical conductivity at 30 DAS and 60 DAS, at 90 DAS and at harvest, brinjal and groundnut exhibited least values of electrical conductivity.

Table 3: Effect of different cultivation practices and various crops on periodical changes in the electrical conductivity (dS m^{-1}) of soil

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Cultivation practices				
C_1: Low budget farming	0.11	0.11	0.10	0.11
C_2: Organic farming	0.10	0.10	0.09	0.10
C_3: Conservation farming	0.08	0.09	0.07	0.09
C_4: Conventional farming	0.09	0.10	0.08	0.10
SE (±)	0.01	0.005	0.01	0.01
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
Crops				
S_1: Groundnut	0.09	0.10	0.08	0.09
S_2: Maize	0.11	0.11	0.10	0.11
S_3: Brinjal	0.08	0.09	0.08	0.09
S_4: Watermelon	0.10	0.10	0.09	0.10
SE (±)	0.01	0.01	0.01	0.01
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
Interaction effect				
SE (±)	**0.01**	**0.01**	**0.01**	**0.01**
CD (P= 0.05)	**N.S.**	**N.S.**	**N.S.**	**N.S.**
General mean	0.10	0.10	0.09	0.10

Organic carbon content

Effect of cultivation practices

The data presented in Table 4 revealed that the organic farming practice manifested the highest organic carbon content (14.70, 15.83, 14.38 and 13.75 g kg^{-1}) however, the conventional farming practice showed least organic carbon content (13.45, 15.15, 14.20 and 13.35 g kg^{-1}) at 30 DAS, 60 DAS, 90 DAS and at harvest, respectively as influenced by different cultivation practices. It was also observed that the organic carbon content of soil was increased from 30 to 60 DAS. The increase in the organic carbon content of soil was due to the straw incorporation which provided a direct carbon source for the formation of soil organic carbon. The organic manures are effective in building up the organic carbon status of soil, since microbial abundance helped in sequestering the mineralized carbon from organic manures and loading in to the soil carbon pool. Thereafter, a decrease in the available organic carbon content was noticed from 60 DAS to harvest of the crops. This was probably due to the decomposition of applied and native organic matter. Gavit *et al.* (2019) [12] noticed that the organic carbon content of different soil first decreased from 30 to 60 DAI and then increased from 60 DAI to 90 DAI and 90 DAI to 120 DAI of incubation.

Effect of crops

The organic carbon content of soil at different stages due groundnut, maize, brinjal and watermelon exhibited non-significant results with a range of 13.65 to 14.18 g kg^{-1} at 30 DAS, 15.10 to 15.85 g kg^{-1} at 60 DAS, 14.18 to 14.63 g kg^{-1} at 90 DAS and 13.25 to 13.78 g kg^{-1} at harvest of the crops. Highest organic carbon content was observed under watermelon at 30 DAS, maize at 60 DAS and brinjal at 90 DAS and at harvest of the crops. The lowest organic carbon content was observed under maize at 30 DAS and at harvest, watermelon at 60 DAS and groundnut at 90 DAS. Similar trend and ranges of organic carbon content were also quoted by Bankar (2017) [4] in sweet corn. A decrease of organic carbon content with passage of time from 60 DAS to harvest of the crop was reported by Malavade (2019) [16] in brinjal.

Table 4: Effect of different cultivation practices and various crops on periodical changes in the organic carbon (g kg^{-1}) content of soil

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Cultivation practices				
C_1: Low budget farming	13.65	15.70	14.35	13.53
C_2: Organic farming	14.70	15.83	14.38	13.75
C_3: Conservation farming	13.48	15.58	14.33	13.50
C_4: Conventional farming	13.45	15.15	14.20	13.35
SE (±)	0.27	0.24	0.29	0.16
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
Crops				
S_1: Groundnut	13.75	15.78	14.03	13.50
S_2: Maize	13.65	15.85	14.43	13.25
S_3: Brinjal	13.70	15.53	14.63	13.78
S_4: Watermelon	14.18	15.10	14.18	13.60
SE (±)	0.29	0.24	0.25	0.19
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
Interaction effect				
SE (±)	0.57	0.47	0.50	0.38
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
General mean	13.82	15.57	14.32	13.53

Available macronutrient content

Available nitrogen content

The data summarised in Table 5 indicated that the different cultivation practices significantly influenced the available nitrogen content in soil and it ranged from 262.12 to 275.71 kg ha^{-1} at 30 DAS, 269.17 to 290.08 kg ha^{-1} at 60 DAS, 260.55 to 278.58 kg ha^{-1} at 90 DAS and 256.37 to 273.62 kg ha^{-1} at harvest of the crops.

Effect of cultivation practices

Among the different cultivation practices, conservation farming practice showed significantly higher results in respect of available nitrogen content at 30 DAS (275.71 kg ha^{-1}), 60 DAS (290.08 kg ha^{-1}), at 90 DAS (278.58 kg ha^{-1}) and at harvest (273.62 kg ha^{-1}) of the crops in soil. The conservation farming practice was at par with conventional farming practice and both the treatments were significantly superior to the organic farming and low budget farming practices. At 90 DAS, the conservation farming practice was at par with the conventional farming mn and organic farming practices. All these three treatments were significantly superior over low budget farming practice in the available nitrogen content of soil. The significantly higher content of available nitrogen in conservation farming practice may be due to the impervious plastic film which avoided leaching of the nutrients from the soil, leading to an accumulation of nitrogen. Additionally, under reduced tillage system, crop residue may have been made available to soil microorganisms at a slower rate for a longer duration, soil temperature was lowered down and therefore, the soil became more moist and the soil may be in a less oxidative condition. All these facts helped in enhancing the content of available nitrogen in soil.

Table 5: Effect of different cultivation practices and various crops on periodical changes in the available nitrogen (kg ha^{-1}) content of soil

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Cultivation practices				
C_1: Low budget farming	262.12	269.17	260.55	256.37
C_2: Organic farming	265.78	272.57	268.65	262.38
C_3: Conservation farming	275.71	290.08	278.58	273.62
C_4: Conventional farming	271.53	285.11	272.83	266.82
SE (±)	2.42	2.36	2.97	2.01
CD (P= 0.05)	8.38	8.16	10.27	6.94
Crops				
S_1: Groundnut	272.05	286.16	285.38	277.27
S_2: Maize	263.16	271.79	262.12	258.72
S_3: Brinjal	268.91	274.14	265.51	261.07
S_4: Watermelon	271.00	284.85	267.61	262.12
SE (±)	2.86	1.63	2.23	1.70
CD (P= 0.05)	N.S.	4.76	6.49	4.96
Interaction effect				
SE (±)	5.72	3.26	4.46	3.40
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
General mean	268.79	279.23	270.15	264.80

The increase in available nitrogen content from 30 to 60 DAS might be attributed to the direct addition of nitrogenous fertilizer to the available pool of the soil, it may also be due to the use of organic manures and their residual effect and build up in organic nitrogen fractions of the soil due to biochemical degradation and mineralization. The increase in available nitrogen status over periods of observation may partly be due to the decomposition of organic matter and split application of nitrogenous fertilizers. The incorporated straw may facilitate the transformation of soil nitrogen into a slowly available nitrogen source at the rate that suits the needs of crops, possibly increasing the nitrogen content in soil. The decrease in available nitrogen content from 60 DAS to harvest was observed which may be because of the fact that, during the said time span, the crops started their reproductive growth that led to higher consumption of nutrients by crops.

Salvi *et al*. (2015) [21] reported significantly higher available nitrogen (328.84 kg ha^{-1}) content due to application of manure, inorganic fertilizers and biofertilizers as compared to absolute control and RDF alone. Biradar *et al*. (2020) [5] also reported a decrease in available nitrogen content from 60 DAS to harvest of crop and found a significantly higher nitrogen content in the treatment receiving 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 20 t FYM ha^{-1} under yam bean cultivation in Konkan region of Maharashtra.

Effect of crops

The data related to periodical changes in the available nitrogen content of soil at different stages due to the effect of various crops are presented in Table 5 which varied from 263.16 to 272.05 kg ha^{-1} at 30 DAS, 271.79 to 286.16 kg ha^{-1} at 60 DAS, 262.12 to 285.38 kg ha^{-1} at 90 DAS and 258.72 to 277.27 kg ha^{-1} at harvest of the crops. At 60 DAS, 90 DAS and at harvest, groundnut exhibited higher values of available nitrogen content (286.16, 285.38 and 277.27 kg ha^{-1}) in soil. At 60 DAS, groundnut was at par with watermelon and both the treatments were significantly superior over brinjal and maize. At 90 DAS as well as at harvest of the crops, groundnut was superior to watermelon, brinjal and maize. The highest available nitrogen content in groundnut crop might be attributed to the fixation of nitrogen by the nodules formed and the lowest available nitrogen content in maize followed by brinjal may be due to the exhaustive nature of the crops. Salvi *et al*. (2015) [21] observed decreasing trend of available nitrogen content from 45 DAS to harvest of okra in Coastal region of Maharashtra. Decreasing trend in the available nitrogen content from 60 DAS to harvest of snake gourd in lateritic soils was also reported by Mahale (2017) [15].

Available phosphorus

The periodical changes in the available phosphorous content of soil as influenced by low budget farming, organic farming, conservation farming and conventional farming practices as well as of different crops *viz*, groundnut, maize, brinjal and watermelon grown in Alfisols of Konkan region are presented in Table 6. The mean values of available phosphorous content at 30 DAS, 60 DAS, 90 DAS and at harvest were 11.78, 12.51, 9.52 and 9.17 kg ha^{-1}, respectively. Similar ranges of available phosphorous content in lateritic soils were found by Biradar *et al*. (2020) [5] and she reported the range of available phosphorous from 12.38 to 17.47 kg ha^{-1} at 30 DAS, 6.46 to 12.35 kg ha^{-1} at 60 DAS and 4.23 to 10.61 kg ha^{-1} at harvest of Yam bean.

Effect of cultivation practices

The data summarised in Table 6 indicated that the different cultivation practices significantly influenced the available phosphorous content in soil which ranged from 11.52 to 12.02 kg ha^{-1} at 30 DAS, 11.96 to 12.99 kg ha^{-1} at 60 DAS, 9.16 to 9.79 kg ha^{-1} at 90 DAS and 8.76 to 9.51 kg ha^{-1} at harvest of the crops.

At 30 DAS, conservation farming practice showed highly significant outcome on the available phosphorous content (12.02 kg ha^{-1}) in soil and the same treatment was at par with conventional farming practice (11.81 kg ha^{-1}) and organic farming practice (11.75 kg ha^{-1}). All the three treatments were significantly superior over low budget farming practice (11.52 kg ha^{-1}). The treatment, conservation farming practice exhibited highly significant results on the available phosphorous content (12.99 kg ha^{-1}, 9.79 kg ha^{-1} and 9.51 kg ha^{-1}) in soil at 60 DAS, 90 DAS and at harvest, respectively. However, it was at par with conventional farming practice and both conservation farming, conventional farming practices were significantly superior over organic farming and low budget farming practices. The higher values of the available phosphorous content of soil in the treatment consisting conservation farming practice may be attributed to the greater temperature due to mulching. The plastic mulch might have changed the soil moisture content and aeration conditions, which in turn resulted in the changes of soil microbial communities and redox potential, thus intensifying the soil phosphorus status. The addition of phosphorus through manure application also increased the levels of different phosphorus forms and the phosphorus saturation of the near-surface soil zone in a no-tillage system (Pavinato *et al*. 2010) [17]. Zhang *et al*. (2013) [28] also suggested the short-term no-tillage improved phosphorous availability in surface soils.

Table 6: Effect of different cultivation practices and various crops on periodical changes in the available phosphorous (kg ha^{-1}) content of soil

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Cultivation practices				
C_1: Low budget farming	11.52	11.96	9.16	8.76
C_2: Organic farming	11.75	12.34	9.50	9.10
C_3: Conservation farming	12.02	12.99	9.79	9.51
C_4: Conventional farming	11.81	12.75	9.64	9.34
SE (±)	0.09	0.10	0.08	0.07
CD (P= 0.05)	0.30	0.34	0.28	0.25
Crops				
S_1: Groundnut	12.02	12.83	9.71	9.38
S_2: Maize	11.28	12.27	9.32	8.95
S_3: Brinjal	11.97	12.66	9.66	9.36
S_4: Watermelon	11.83	12.28	9.40	9.02
SE (±)	0.10	0.13	0.07	0.08
CD (P= 0.05)	0.28	0.37	0.20	0.24
Interaction effect				
SE (±)	0.19	0.26	0.14	0.17
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
General mean	11.78	12.51	9.52	9.17

Increase in available phosphorus content from 30 to 60 DAS might be attributed to the direct addition of phosphorus through fertilizer to the available pool of the soil and also may be due to synergistic effect of nitrogen with phosphorus which increased the availability of phosphorous in the soil. In acid Alfisols of Himachal Pradesh, Romil Sood (2003) [19] also observed increase in available phosphorus with the increasing levels of nitrogen under open field conditions. The gradual increase in available phosphorous content along with application of organic manure was clearly observed from 30 to 60 DAS, which might be due to the rapid mineralization of organic phosphorous content in manure and partly due to solubilization of native insoluble inorganic phosphorous by organic acids produced as a result of decomposition. The straw incorporation management in low budget farming practices presumably leaded to the accumulation of more organic matter at the surface soil, which decreases phosphorous sorption by inorganic colloids and may therefore lead to an increased available phosphorous content of soil.

The increase in available phosphorous content due to the application of Shivan green leaf manure @ 10 t ha^{-1} at onset of monsoon + 100 percent recommended dose of nitrogen, phosphorous, and potassium was reported by Salvi (2007) [22]. Dhopavkar (2018) [8] reported that the application of 50 kg P_2O_5 ha^{-1} significantly increased the available phosphorus content of soil over no application of phosphorus at 30, 60, 90 DAT and at harvest of chilli in Alfisols of Konkan region.

Effect of crops

The periodical changes in the available phosphorous content of soil due to various crops (Table 6) ranged from 11.28 to 12.02 kg ha^{-1} at 30 DAS, 12.27 to 12.83 kg ha^{-1} at 60 DAS, 9.32 to 9.71 kg ha^{-1} at 90 DAS and 8.95 to 9.38 kg ha^{-1} at harvest of the crops.

At 30 DAS, 60 DAS, 90 DAS and at harvest, groundnut showed superior values of the available phosphorous content (12.02, 12.83, 9.71 and 9.38 kg ha^{-1}) in soil. However, at 30 DAS it was at par with brinjal and watermelon. At 60 DAS, 90 DAS and at harvest, it was at par with brinjal and both groundnut and brinjal were significantly superior over watermelon and maize. The rhizospheric soil of groundnut has been considered a reservoir for plant growth-promoting rhizobacteria. Malavade (2019) [16] also reported an increase in phosphorous content from 30 to 60 DAT and then decreased up to the harvest under brinjal crop.

Available potassium

The observations recorded at an interval of 30, 60, 90 DAS and at harvest on the available potassium content under the study are presented in Table 7, with mean values of 298.48, 323.12, 286.44 and 272.72 kg ha^{-1}, respectively.

Effect of cultivation practices

From the data mentioned in Table 7, it was indicated that there are significant differences in the available potassium content under different cultivation practices in the soil, which ranged from 269.92 to 318.08 kg ha^{-1} at 30 DAS, 300.16 to 341.60 kg ha^{-1} at 60 DAS, 252 to 316.96 kg ha^{-1} at 90 DAS, and 245.28 to 291.20 kg ha^{-1} at harvest of the crops.

Table 7: Effect of different cultivation practices and various crops on periodical changes in the available potassium (kg ha^{-1}) content of soil

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Cultivation practices				
C_1: Low budget farming	269.92	300.16	252.00	245.28
C_2: Organic farming	296.80	315.84	266.56	265.44
C_3: Conservation farming	318.08	341.60	316.96	291.20
C_4: Conventional farming	309.12	334.88	310.24	288.96
SE (±)	3.83	8.15	4.51	3.71
CD (P= 0.05)	13.24	28.19	15.62	12.85
Crops				
S_1: Groundnut	273.28	305.76	269.92	259.84
S_2: Maize	309.12	336.00	288.96	272.16
S_3: Brinjal	287.84	312.48	281.12	262.08
S_4: Watermelon	323.68	338.24	305.76	296.80
SE (±)	7.32	6.11	6.18	5.64
CD (P= 0.05)	21.35	17.83	18.03	16.45
Interaction effect				
SE (±)	14.63	12.22	12.35	11.27
CD (P= 0.05)	N.S.	N.S.	N.S.	N.S.
General mean	298.48	323.12	286.44	272.72

The conservation farming practice showed higher available potassium content (318.08, 341.60, 316.96 and 291.20 kg ha^{-1}) at 30, 60, 90 DAS and at harvest of the crops in soil and it showed at par results with conventional farming practices at 30, 90 DAS and at harvest of the crops and at 60 DAS, it was at par with conventional and organic farming practices. Significantly superior available phosphorous content was observed by conservation and conventional farming practices over organic and low budget farming practices at 30, 90 DAS and at harvest of the crops. At 60 DAS, all the three treatments were significantly superior over low budget farming practice. The significantly highest available potassium content in conservation farming may be due to the impervious plastic film which avoided leaching of the nutrients from the soil, leading to an accumulation of potassium. Sá *et al.* (2009) [20] verified a higher concentration of potassium in no-tillage, assigning it to the impact of larger amounts of potassium rich crop residues and to the increase in soil organic matter, which increased CEC and led to retention of potassium in the soil.

A scrutiny of the data indicated that the available status of potassium under all the treatments showed an increase from 30 to 60 DAS, a decrease from 60 DAS to harvest of the crops. The increase in available potassium content under different cultivation practices from 30 to 60 DAS may be due to release of nutrient in soil from native pool as well as their residual effects. The increase in potassium availability might be due to synergistic effect of nitrogen with phosphorus and potassium which increased the availability of potassium in soil. The higher availability of potassium in soil may also be due to beneficial effect of organic manures on the reduction of potassium fixation, added organic matter which interacted with potassium clay to release potassium from non-exchangeable fraction to the available pool. According to Tisdale *et al.* (1995) [26], organic matter improves CEC, which reduces potential leaching losses of elements such as K^+, Ca^{2+} and Mg^{2+} and increases their availability.

The above-mentioned findings showed high resemblance with results mentioned by Rathod *et al.* (2018) [18] who reported a significantly highest potassium content in treatment receiving constant dose of phosphorous and potassium along with 50 percent nitrogen through poultry manure and 50 percent recommended dose of nitrogen followed by treatment containing 50 percent nitrogen from FYM application. Also, a decreasing trend in potassium content from 60 DAS to harvest in lateritic soils was noticed.

Effect of crops

The data regarding the effect of various crops (Table 7) on the available potassium content of soil at different stages due to various crops varied from 273.28 to 323.68 kg ha^{-1} at 30 DAS, 305.76 to 338.24 kg ha^{-1} at 60 DAS, 269.92 to 305.76 kg ha^{-1} at 90 DAS and 259.84 to 296.80 kg ha^{-1} at harvest.

At 30, 60 and 90 DAS, watermelon crop showed highly significant results on the available potassium content (323.68, 338.24 and 305.76 kg ha^{-1}, respectively) in soil and it was at par with maize. Both watermelon and maize exhibited significantly superior effect over brinjal and groundnut. At harvest watermelon indicated significantly superior effect on available potassium content (296.80 kg ha^{-1}) in soil over maize, brinjal and groundnut. The significantly higher values of available potassium content in watermelon may be due to the difference in the root CEC of the crops. Watermelon being a dicot may have absorbed more divalent cations compared to monovalent cations like potassium, possibly resulting in more available potassium content in the soil.

Kokare et al. (2015) [14] reported that, at harvest of chilli, the available potassium content of soil decreased as compared to the 60 and 90 DAT stages. Salvi *et al*. (2015) [15] also observed significantly highest available potassium content in the treatment containing organic manure, inorganic fertilizers and biofertilizers and they observed a considerable decrease in potassium content from 45 DAS to 120 DAS of okra in Konkan region of Maharashtra.

Interaction effect

The interaction effect between different cultivation practices and various crops (Table 5, 6 and 7) was statistically non-significant in respect to the available nitrogen, available phosphorous and available potassium content of the soil.

Conclusion

It can be concluded from the above results that; the conservation farming practice was best among all the cultivation practices followed while carrying out the experiment in improving the physico-chemical properties and the available macronutrient content of the soil. The influence of brinjal crop was more prominent on the pH of the soil, however, brinjal and groundnut proved to improve the electrical conductivity of the soil. Highest organic carbon content was observed under watermelon, maize and brinjal at different stages of growth of the crops. The higher availability of nitrogen and phosphorous was seen under the groundnut crop and watermelon exhibited higher availability of potassium in soil.

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