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Phenolic, Antioxidant and Free Radical-Scavenging Properties of Various Parts of Indian Moringa (*Moringa Oleifera*) during the winter season

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Abstract

The present investigation was conducted to compare Phenolic, Antioxidant, and Free Radical-Scavenging Properties of Various Parts of Indian Moringa (Moringa Oleifera) during the winter season collected from various locations. Three districts viz Jaipur, Dehra Dun, and Gwalior were selected randomly (one from each state of Rajasthan, Madhya Pradesh, and Uttarakhand) for collection of the samples. The samples of the fresh flowers, tender, and mature leaves, and seeds of Moringa oleifera, were collected from three different agroforest locations selected randomly from each district in January 2022. The samples were extracted and analyzed for total phenolic antioxidant-free radical-scavenging properties. The two-way ANOVA with the replication technique of statistical analysis was used to draw a valid conclusion. It can be concluded on behalf of the results that the Indian moringa plant has rich phenolic and antioxidant and free radical-scavenging properties. The mature leaves were superior followed by tender leaves, flowers, and seeds in this respect.

Keywords: Antioxidant, Free Radical-Scavenging, Moringa flower, Moringa leaves, Moringa Oleifera, Moringa seed, Phenolic.

Introduction

Indian moringa *(Moringa oleifera)* is extensively scattered and utilized in tropical and sub-tropical regions of the world and is mainly native to India and Africa. The tree is honored as the “miracle tree”, “natural gift”, or “mother’s best friend”, due to the high nutrients in leaves with protein, minerals, β-carotene, and other properties (Leone et al 2015). On behalf of usefulness, almost all parts of this plant can be used as food, in medicines and for industrial purposes, Indian moringa is considered one of the most valuable trees on the planet. It protects living beings against different types of diseases and infections. In India, the plant is commonly used in traditional medicine for a wide range of various sicknesses and disorders. The consumption of a diet supplemented with Indian moringa has the sufficient capacity to provide necessary protection against diseases induced by oxidative stress (Nascimento et al 2017). Indian moringa leaf was approved as a new food resource in China for its high nutritional value and vitamin E content (Ningli et al 2017).

Antioxidation is an important property in preventing and scavenging free radicals. The leaf extracts of Indian moringa have potent antioxidant activity against free radicals, prevent oxidative damage to major biomolecules and afford significant protection against oxidative damage (Sreelatha and Padma 2009). The antioxidant activities of leaf extracts of thirteen Indian moringa cultivars from Thailand, South Africa and the United States of America, etc. (Ndhlala et al 2014) and leaves grown in three different agroclimatic regions (India, Nicaragua, and Niger, respectively) (Siddhuraju et al 2003) have been reported.

Ndhlala et al (2014) reported that the Indian moringa leaves are rich in flavonoids and phenolic compounds with high anti-inflammatory activities, whereas there is no such characterization of the plant collected in Kenya, let alone a systematic comparison of its phytochemicals of three different organs (leaves, seeds, and roots) as well as the correlation to their different biological activities (Coppin et al 2013).

The leaves of Indian moringa have been reported to have better potential as a natural source of antioxidants and anti-inflammatory agents and are found very promising to develop health-promoting dietary supplements (Xu et al 2019). The strong radical scavenging activity has been shown in the different extracts of leaves like aqueous 70% methanol, and 80% ethanol extract. The compound called kaempferol has been identified for its high antioxidant properties in the leaves (Ganatra et al 2012) and can be used to prevent damage caused by a high-fat diet (Paikra 2017). Flavonoids are potent antioxidants with innumerable pharmacological properties showing antidiabetic, hypotensive, and hypolipidemic properties and diminishing hyperlipidemia and atherosclerosis. Quercetin is commonly known to protect insulin-producing pancreatic β cells from oxidative stress induced by streptozotocin (Sekhar et al 2018).

Indian moringa dried leaves are a rich source of polyphenols such as flavonoids and phenolic acids having a common structure like the benzo-pyrone ring, which response to microbial infection in plants. Consumption of these flavonoids has been reported to prevent chronic diseases like cardiovascular diseases and cancer caused by oxidative stress. The concentration of the flavonoid compounds in leaves has been determined to be 5.8 mg/g myricetin, 0.207 mg/g quercetin, and 7.5 mg/g kaempferol respectively. Dried leaves contain quercetin of concentration100mg/100g available in 3-o-β-d-glucoside quercetin form (Vergara-Jimenez et al 2017).

Phenolic acids are also the phenolic compounds that naturally occur in plants derived from hydroxybenzoic acid and hydroxycinnamic acid showing antimutagenic, antioxidant, anti-cancer, and anti-inflammatory properties. Dried leaves of moringa tree leaves are the most plentiful source of Gallic acid with a content of around 1.034 mg/g dry weight and chlorogenic acid and caffeic acid ranging between 0.018 and 0.489 mg/g and 0.409 mg/g respectively (Vergara-Jimenez et al 2017, Gandhi et al 2018, Milla et al 2021).

The present investigation was conducted to compare Phenolic, Antioxidant, and Free Radical-Scavenging Properties of Various Parts of Indian Moringa (*Moringa Oleifera*) during the winter season collected from various locations.

Material and methods

Three districts viz Jaipur, Dehra Dun, and Gwalior were selected randomly (one from each state of Rajasthan, Madhya Pradesh, and Uttarakhand) for collection of the samples. The samples of the fresh flowers, tender, and mature leaves, and seeds of Moringa oleifera, were collected from three different agroforest locations selected randomly from each district in January 2022. The samples were extracted using the method of Swain and Hills (1959); with the necessary modifications (Torres et al 2002). The total phenolic content was assessed following the Folin-Ciocalteu assay method (Singleton and Rossi 1965) with minor modifications (Quettier-Deleu *et al.,* 2000). The results were expressed as gallic acid equivalents. The antioxidant capacity was determined according to the DPPH method (Maria do Socorro et al 2010), based on the quantification of free radical scavenging. The per cent FRS of each sample was calculated following the equation hereunder:

% Free radical scavenging = ((AC-AA) x 100)/AC

[Ac is absorbance values of blank and AA absorbance values of the sample].

For comparing phenolic, antioxidant, and free radical scavenging properties of various parts of Indian moringa from different locations, two-way ANOVA with the replication technique of statistical analysis was implemented (Snedecor, and Cochran 1994) to compare the results. The analysis pack of MS Office Excel, 2016 (UQ Library 2016) was used for the purpose.

Results and discussion

The phenolic properties expressed as mg/100g of gallic acid in various parts of moringa (Table 1; Figure 1) collected from three various locations viz. flower, tender, and mature leaves, and the seed was not different ($P>0.05$). In mature leaves, phenolic properties (168.18±1.77) were highest followed by tender leaves (140.05±2.54) and flowers (111.87±0.91) whereas in seeds (24.69±0.50) it was lowest ($P<0.05$). Nascimento et al (2017) reported the highest phenolic properties in leaves followed by flower and seeds, whereas, Fakurazi et al (2012) reported that among edible parts of moringa the flower extracts contain the highest total phenolic content followed by leaves extract. As far as the numerical values of the phenolic properties in various parts of moringa are concerned, the values confirmed the findings of Nascimento et al (2017).

Table 1: Phenolic properties (mg/100g of gallic acid) in *Moringa oleifera*

Location	Flower	Tender leaf	Mature Leaf	Seed
Gwalior	111.53±0.55	138.15±5.62	167.63±2.16	24.18±0.79
Jaipur	114.83±1.51	139.58±5.18	162.83±0.74	25.83±0.35
Dehra Doon	109.25±1.18	142.43±3.08	174.08±2.80	24.08±1.14
Overall	111.87±0.91	140.05±2.54	168.18±1.77	24.69±0.50

P Value-Flower parts 0.00 and Locations 0.51 and Interaction 0.11.

The antioxidant capacity expressed as of µM Eq Trolox/g in various parts of moringa (Table 2; Figure 2) collected from three various locations viz. flower, tender, mature leaves, and seed were not different ($P>0.05$). In mature leaves, antioxidant capacity (28.26±0.47) was highest followed by tender leaves (26.89±0.42) and flowers (24.28±0.46) whereas in seeds (20.84±0.47) it was lowest (P<0.05). These results verified the observations of Manju et al (2021) and Nascimento et al (2017) reporting freeze-dried Moringa leaves and flowers had better retention in terms of nutrition and antioxidant activities, whereas, Fakurazi et al (2012) reported that among edible parts of moringa the flower extracts contain the antioxidant capacity followed by leaves extract. Fitriana et al (2016) studied that moringa leaves possess antioxidants. As far as the numerical values of the antioxidant capacity in various parts of moringa are concerned, the values confirmed the findings of Nascimento et al (2017).

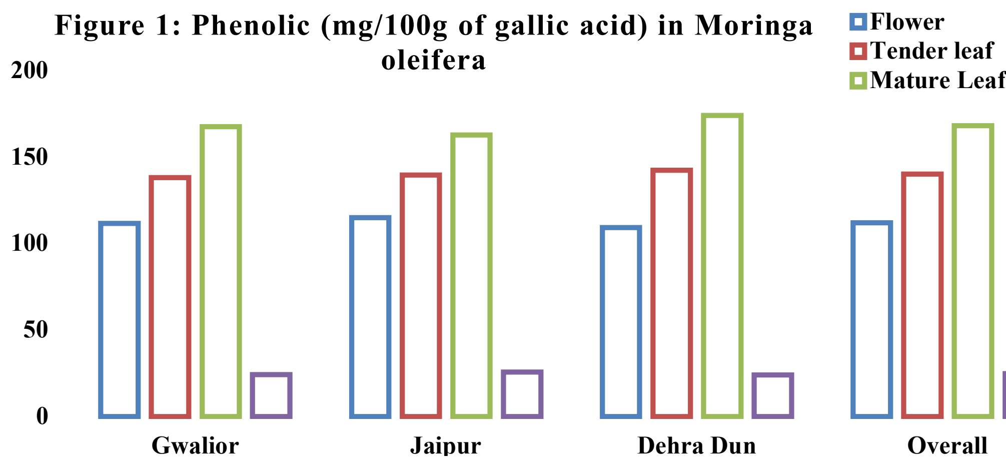
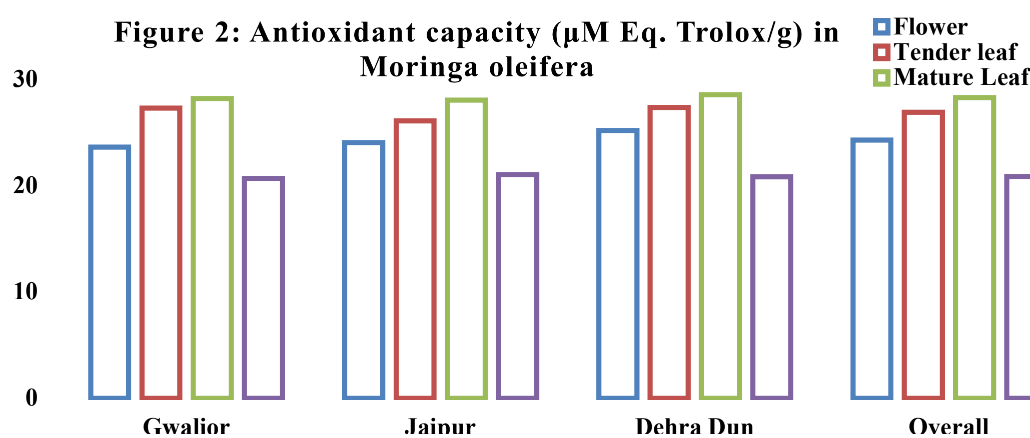


Table 2: Antioxidant capacity (µM Eq. Trolox/g) in *Moringa oleifera*

Location	Flower	Tender leaf	Mature Leaf	Seed
Gwalior	23.60±0.60	27.28±0.99	28.18±1.13	20.68±1.12
Jaipur	24.03±0.89	26.08±0.64	28.05±1.00	21.05±0.85
Dehra Doon	25.20±0.83	27.33±0.45	28.55±0.31	20.80±0.63
Overall	24.28±0.46	26.89±0.42	28.26±0.47	20.84±0.47

P Value-Flower parts 0.00 and Locations 0.49 and Interaction 0.88.

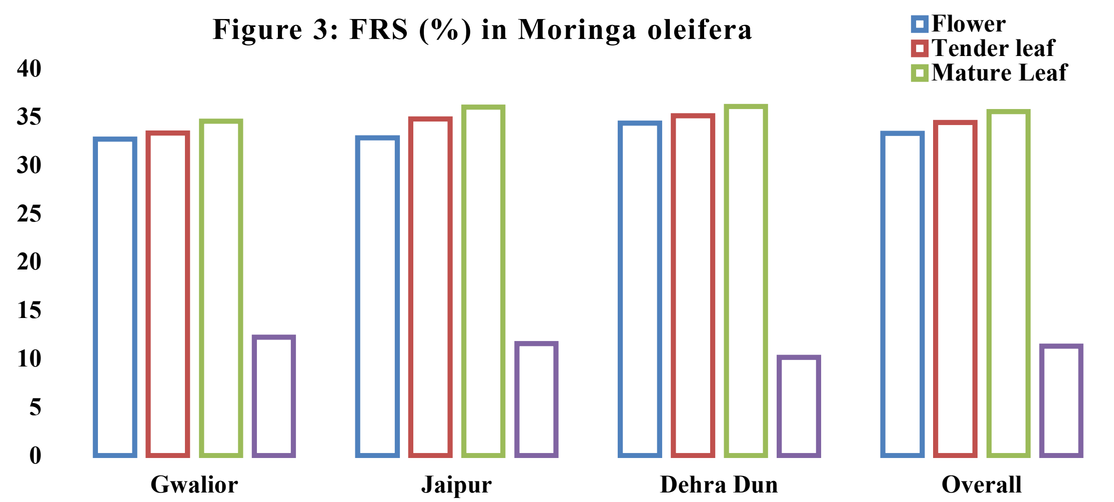


The free radical-scavenging properties in various parts of moringa (Table 3; Figure 3) collected from three various locations viz. flower, tender, mature leaves, and seed were not different (P>0.05). In mature leaves, free radical-scavenging properties (35.58±0.49) were highest followed by that in tender leaves (34.44±0.47) and flowers (33.33±0.41) whereas in seeds (11.33±0.34) it was the lowest (P<0.05). Nascimento et al (2017) reported the highest free radical-scavenging properties in leaves followed by flowers and seeds. As far as the numerical values of the free radical-scavenging properties (%) in various parts of moringa are concerned, the values confirmed the findings of Nascimento et al (2017).

Table 3: Free radical-scavenging properties (%) in *Moringa oleifera*

Location	Flower	Tender leaf	Mature Leaf	Seed
Gwalior	32.75±0.67	33.36±0.92	34.58±0.59	12.25±0.42
Jaipur	32.85±0.48	34.83±0.64	36.05±0.62	11.60±0.46
Dehra Doon	34.38±0.77	35.15±0.75	36.10±1.20	10.15±0.36
Overall	33.33±0.41	34.44±0.47	35.58±0.49	11.33±0.34

P Value-Flower parts 0.00, Locations 0.0.31 and Interaction 0.07.



It can be concluded on behalf of the results that the Indian moringa plant has rich phenolic and antioxidant and free radical-scavenging properties. The mature leaves were superior followed by tender leaves, flowers, and seeds in this respect.

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Characterization of soil fertility as influenced by age of *Eucalyptus spp* plantation and site conditions in the central highland of Eritrea

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Abstract

The present investigation was carried out to characterize the soil fertility as influenced by age and site of eucalyptus plantation enclosures in moist highland zones of Eritrea. Three sites: Serejeka, Dem-Sebai, and Emba-Dorho, and; three ages: 7, 16, and 26 years after planting were selected for the study. No significant difference was observed in bulk density with age and site. pH showed a highly significant difference with age but non-significant with the site. Soil organic carbon showed a significant difference with age. A highly significant difference in soil nitrogen content at the Serejeka site, but no significant difference at Dem-Sebai and Emba-Dorho, was observed for age. The amount of available phosphorous in the forest plantations and the non-forested control was low. There was a significant difference in available phosphorus with age only in Emba-Dorho.

Key Words: Afforestation, Enclosures, Organic carbon, Nitrogen, Phosphorus.

Introduction

Eucalyptus was introduced to Eritrea in 1922 (Berhane and Elias 2004); in which *Eucalyptus globulus*, *Eucalyptus camaldulensis, and Eucalyptus cladocalyx* were grown for fuel wood, pole wood production, and water conservation to rehabilitate degraded hillsides. The ongoing expansion of *Eucalyptus* plantations has been the focus of two major debates on the environmental impacts and the role of the species in the livelihoods of the population. The argument on the environmental influences of the species is associated to soil acidification, nutrient exhaustion, allelopathic effects, and excessive water use and hence drying up of water points, particularly in arid areas like Eritrea. But owing to its fast growth, high biomass production, and browsing resistance (Kidanu et al 2004), it is an important multipurpose species. Empirical evidence to either support or refute the supposed ecological impacts of the tree species in Eritrea is scanty, anecdotal, and poorly understood. Hence, there was a need to address the effect of *Eucalyptus* plantation enclosures on soil nutrient status and quantify the changes in soil nutrient stock and soil quality along a chronosequence of forest plantations. The total area set as permanent enclosures is 86,367.00 ha and temporary enclosures are 25,167.00 ha (FAO 2010). The effectiveness of such interventions, particularly in terms of soil amelioration, productivity, restoration of degraded vegetation, and regeneration of the indigenous species had not been systematically investigated. Hence the present investigation was carried out to characterize the conditions e.g. soil fertility of the afforested enclosures as influenced by age and site conditions in the moist highlands of Eritrea. The aim was to examine the spatial and temporal dynamics of the Eucalyptus plantations because of some soil attributes and find out if the species improves or degrades the land productivity.

Materials and Methods

Eritrea is located along the Red Sea with varied topography, rainfall, and climate. Its climate ranges from hot and semi-desert near the Red Sea to sub-humid in isolated micro catchments. The central highlands are semi-arid for most parts of the year; and the monsoon last from mid-June up to mid-September. Three sites in the central highlands of Zoba Maekel namely: Dem-Sebai located between 476000 and 484000 UTM latitude and 1704000 and 1696000 UTM longitude; Emba-Dorho and Serejeka located between 476000 and 484000 UTM latitude and 1712000 and 1704000 UTM longitude, were selected for the present investigation. The altitudes of Zoba Maekel ranged from 1,300 MAS l to 2,610 MAS l. Mean annual rainfall in the area was 400 mm with minimum and maximum temperatures of 4.3^0C and 25.5^0C, respectively. It is characterized by undulating planes with slopes ranging from below 2% to steep slopes greater than 50%, (MoA 2013).

Considering the heterogeneity of soil properties at the spatial scale of a few meters or less, particularly for soil organic matter content driven by litter inputs; a preliminary soil survey was carried out to get a general impression of the sites. To accommodate spatial variation at a plot or compartment level, due considerations were made while measuring changes in surface soil chemical and physical properties. Hence, to minimize the effect that would arise from the difference in topography and aspect, samples were strategically collected in the field from the different plantation age groups in selected forest inventory plots. A 'W' shaped sampling procedure was used to select the points for sampling which involved the use of a coordinated system where the points sampled were at the intersection of two lines of approximately 15 paces in a 'W' shape to the depth of 0-20cm. (Carter and Gregorich 2008)

Soil samples were taken for physical and chemical characteristics analysis from each of the square sample plots using a sharp-edged steel cylinder with a diameter of 5 cm (25 cm^2) for bulk density determination and composite soil samples (McFee and Stone 1965). The sampling units were then thoroughly mixed to form a composite sample. The soil was air-dried and grounded to pass through a 2 mm sieve for soil analysis at National Agricultural Research Institute (NARI) laboratory using standard procedures. Bulk density: London (1991); mechanical analysis: hydrometer method, (Ryan et al 2001; EC (DSM^{-1}) and pH were determined in a 1:5 soil suspensions deionized water solution using conductivity meter and a digital potentiometric pH-meter, respectively; organic carbon was obtained by the wet dichromate acid oxidation method; total nitrogen was determined using the Kjeldahl distillation method; available phosphorus (ppm) was determined using sodium bicarbonate extraction. Analysis of Variance (ANOVA) was used to detect any significant differences in physicochemical properties on the surface soils (0-20 cm) of different ages of forests and sites. All statistical tests were conducted with Gen Stat Discovery edition 2013.

Results and Discussion

The bulk density ranged from 1.27 Mg m^{-3} to 1.51 Mg m^{-3}, and there were no significant differences among age and site (Table 1). The average bulk density in

Emba-Dorho was the highest (1.41 Mg m^{-3}) and the average bulk densities at Dem-Sebai and Serejeka were almost similar. The smallest (1.27 Mg m^{-3}) bulk density was recorded at Serejeka at age seven.

The results, especially of Serejeka where the bulk density of the forested land was surpassed by the non-forested land, were similar to the findings of Wicharuck et al (2010). Ambachew et al (2012) also reported a considerable decrease in soil bulk density when a forest was established on cultivated soils.

Table 1: Mean values of BD (Mg m^{-3}), pH, and EC (dS m^{-1}) concerning age and site variations

Plantation Age	Serejeka			Dem_sebai			Emba-Dorho		
	BD	pH	EC	BD	pH	EC	BD	pH	EC
7 years	1.27	5.92	0.51	1.32	5.88	0.55	1.35	5.90	0.53
16 years	1.34	6.14	0.38	1.39	6.30	0.55	1.38	6.22	0.56
26 years	1.34	6.44	0.57	1.32	6.40	0.58	1.38	6.56	0.65
Control (non-forested)	1.40	6.78	0.53	1.37	6.54	0.56	1.51	6.40	0.56
G. Mean	1.34	6.32	0.50	1.35	6.28	0.56	1.41	6.27	0.58
F pr.	0.385	0.027	0.108	0.206	0.048	0.096	0.062	0.019	0.096
CV%	1.2	0.8	8.9	3.4	3.5	15.2	1.9	1.8	15.2
s.e.d. +/-	0.071	0.209	0.158	0.033	0.175	0.085	0.051	0.148	0.085
L.S.D. (5%)	NS	0.511	NS	NS	0.428	NS	NS	0.363	NS

The results (Table 1) revealed that there was a significant difference with increasing age, but no significant difference with site variations. pH ranged from moderately acidic (5.88 to 5.92) at age seven to slightly acidic (6.44 to 6.56) at age twenty-six years, similar results were reported by Hazelton and Murphy (2007). These values were lower than those reported by Atzbaha et al (1998) where they ranged from 6.69 to 7.59 for the Sesewa catchment area near the Dem-Sebai site. The decreased soil acidity at younger ages may be attributed to the higher density of trees at these ages where higher stocking density leads to higher litter fall and fresh organic matter accumulation on the forest floor, which lowers the soil pH.

The values of EC showed significant differences with age and site. EC of the control plots (non-forested land), was lower than the plantation. Maximum EC (0.65 DSM^{-1}) was recorded at age twenty-six at the Dem-Sebai site. Lowest EC (0.38 DSM^{-1}) was recorded at age sixteen in Serejeka (Table 1). Invariably, EC in all ages and sites was low suggesting that the soils of these plantations were non-saline (Landon 1991). Atzbaha et al (1998) reported an EC of 0.33 dS m^{-1} for the Sesewa catchment located nearby the Dem-Sebai site. EC is heavily dependent on climatic conditions where for instance, soils of sub-humid tropics had sufficient rainfall to flush out base-forming cations from the root zone.

SOC showed a considerable statistical difference among the different age groups (Table 2). Soil samples from seven years old plantations had higher SOC compared to the sixteen and twenty-six-year-old plantations. Comparing the SOC across age showed a highly significant difference (Fpr=0.003) for the Serejeka site and a significant difference (Fpr=0.038) for both

Dem-Sebai and Emba-Dorho sites. As age increased, the SOC content decreased up to the age of sixteen years and then started to increase towards the age of twenty-six. These results were similar to the reports of Atzbaha et al (1998).

There was a highly significant difference in soil nitrogen content for age differences within the Serejeka site but no significant difference in soil N content with age at Dem-Sebai and Emba-Dorho. There was similarity in soil nitrogen content of the older age forest plantation and the non-forested control but the N content of the soil samples taken from plots of age seven years was considerably high as compared to the non-forested control and even the older age plantations. These results are comparable with the findings of Chen et al (2004).

Table 2: Mean values of SOC%, N% and P (ppm) concerning age and site variations

Plantation Age	**Serejeka**			**Dem sebai**			Emba-Dorho		
	SOC	N	P	SOC	N	P	SOC	N	P
7 years	1.97	0.13	1.54	2.03	0.20	4.68	2.01	0.17	3.46
16 years	1.08	0.06	0.20	1.25	0.10	3.51	1.98	0.11	3.40
26 years	1.19	0.08	1.10	1.78	0.10	3.18	2.58	0.11	4.48
Control(non-forested)	0.90	0.06	1.60	0.43	0.10	2.01	1.18	0.10	2.03
G. Mean	1.29	0.08	1.11	1.37	0.13	3.34	1.94	0.12	3.34
F pr.	0.003	0.006	0.079	0.038	0.269	0.098	0.038	0.124	0.039
CV%	9.11	15.9	35.1	19.0	18.4	22.1	19.0	16.5	19.0
s.e.d. +/-	0.172	0.013	0.472	0.348	0.034	0.944	0.348	0.375	0.612
L.s.d. (5%)	0.421	0.032	NS	1.702	NS	NS	0.851	NS	1.497

There was a significant difference in available phosphorus with age only in Emba-Dorho. There was a highly significant difference in mean phosphorus availability among the sites. The average means of phosphorous at Dem-Sebai and Emba-Dorho was 3.34 ppm whereas in Serejeka it was 1.11ppm only (Table 2). These were comparable to the results reported by Atzbaha et al (1998). Phosphorus availability was affected by the pH of the soil as P is always found in a fixed form at lower pH. The pH of these forest plantations ranged from 5.88 - 6.78 (Table 1) which is moderately acidic to slightly acidic (Hazelton and Murphy 2007) which makes P to be fixed and unavailable to the plant.

Conclusions

Bulk density did not show any difference with age and site whereas EC in all ages and sites was low suggesting that the soils of these plantations were non-saline; it was further observed that the soil pH increased with increasing age of the stand in the three sites. The comparison of the soil organic carbon across age showed a different level of variations in the three sites. There was also a considerable difference observed in soil nitrogen content among the forest plantations. The amount of available phosphorous in the forest plantations and the non-forested control was low and a significant difference in available phosphorus with age was observed only in Emba-Dorho.

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Seasonal variation in antioxidant properties of various parts of the *Moringa oleifera* plant collected from different Indian locations

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Abstract

The present study was an attempt to find out the antioxidant properties of various parts of the Moringa oleifera plant collected from different Indian locations in various seasons. Three Indian locations viz Jaipur, Dehra Dun, and Gwalior were selected randomly for collection of the samples of the fresh flowers, tender and mature leaves, and seeds of Moringa oleifera. The samples were collected from three different agroforest locations selected randomly from each district during each calendar month of the year 2021-22. The samples were extracted and antioxidant properties were determined according to the DPPH method, based on the quantification of free radical scavenging. For comparing antioxidant properties, the factorial ANOVA technique of statistical analysis was implemented and an analysis pack of MS Office Excel, 2016 was used to compare data. The flowers collected from Jaipur had superior and seeds from Gwalior had inferior antioxidant properties. Flowers and tender leaves were better compared to mature leaves and seeds and the month of January was the better and June poor season to yield antioxidant properties in the plant.

Keywords: Antioxidant, Locations, Months, *Moringa oleifera*, Organs.

Introduction

Human beings are exposed to both endogenous and exogenous sources of free radicals including exposure to UV light, smoking, ionizing radiation, certain organic solvents, pollutants, and industrial waste or the metabolism (Boonchum et al 2011). Free radicals are supposed to be harmful as they influence several metabolic activities of the cells. The presence of free radicals in the human body might lead to dangerous diseases such as coronary heart disease, cancer, diabetes mellitus, atherosclerosis, arthritis, neurodegenerative diseases, and Alzheimer's disease and contribute to the aging process of the body (Gutteridge 1995, Pong 2003, Pezzuto and Park 2015). The inclusion of antioxidants in food or as supplements can protect the body against these diseases (Moon and Shibamoto 2009). These issues can occur if antioxidant defenses in the body are inadequate. Therefore, it is desirable to increase dietary antioxidants (Soong and Barlow 2004). Safety concerns about the use of synthetic antioxidants have been expressed in recent reports (Sun and Ho 2005, Hossain et al 2008), while edible plant parts rich in antioxidants, especially spices and herbs, are attracting the focus of current interest (Nakatani 1997, Rice-Evans et al 1997). Natural antioxidants are always recommended over synthetic ones because they are viewed as less toxic and more potent than synthetics (Boonchum et al 2011). For example, a cup of coffee contains 200-550 mg, while a cup of tea 150–200 mg, and a glass of wine 200–800 mg of polyphenols (Lakenbrink et al 2000). As the natural antioxidant vitamin C, tocopherols, flavonoids, and other phenolic compounds are well known and present in certain plants (Laandrault et al 2001).

Moringa oleifera is a plant that has been identified to contain natural antioxidants (Iqbal and Bhanger 2006). Siddhuraju and Becker (2003) analyzed the antioxidant activity of this plant from India, Nicaragua, and Niger. The antioxidant properties of the various parts of the *Moringa oleifera* plant especially leave and flowers were superior to those of selected vegetables (cabbage, spinach, broccoli, cauliflower, and peas) (Pakade et al 2013). Antioxidants of the leaves could quench ABTS+ rather than reducing power and ability to quench DPPH radicals, while antioxidants of the pods and seeds possessed reducing power equal to or higher than the ability to quench DPPH and ABTS radicals (Wangcharoen and Gomolmanee 2011). It protects against STZ-induced diabetes. The MOMtE exhibited significant antidiabetic and antioxidant activity and active constituents that may be isolated from the extract for evaluation in future clinical studies (Gupta et al 2012). The plant has been associated with a variety of nutritional, medicinal, and miscellaneous uses (Singh et al 2014) along with its antioxidant properties (Santos et al 2012). Pakade et al (2013) explained why *Moringa oleifera* forms part of the diet of people in many developing countries.

The present study was an attempt to find out the antioxidant properties of various parts of the *Moringa oleifera* plant collected from different Indian locations in various seasons.

Materials and Methods

Three Indian locations viz Jaipur (Rajasthan), Dehra Dun (Uttarakhand), and Gwalior (Madhya Pradesh) were selected randomly (one from each state) for collection of the samples of the fresh flowers, tender and mature leaves, and seeds of *Moringa oleifera*. The samples were collected from three different agroforest locations selected randomly from each district during each calendar month of the year 2021-22. The samples were extracted using the method of Swain and Hills (1959); with the necessary modifications (Torres et al 2002). The antioxidant capacity was determined according to the DPPH method (Maria do Socorro et al 2010), based on the quantification of free radical scavenging. For comparing antioxidant properties of various parts of Indian moringa during different calendar months of the year from different locations, factorial ANOVA with the replication technique of statistical analysis was implemented (Snedecor and Cochran 1994) to compare the results. The analysis pack of MS Office Excel, 2016 (UQ Library 2016) was used for the purpose.

Results and Discussion

Antioxidant properties (µM Eq. Trolox/g) of various organs of the *Moringa oleifera* plant collected from various Indian locations along with their interaction have been presented in Tables 1 and 2. The antioxidant properties were significantly higher ($P<0.05$) in the flower in comparison to those in mature leaves and seeds but nonsignificant ($P>0.05$) than in tender leaves. The interaction between location and various parts of the *Moringa oleifera* tree was also recorded as significant ($P<0.05$) and revealed that the flowers collected from Jaipur had superior and seeds from Gwalior had inferior antioxidant properties. The trends recorded revealed that the exposure to the antioxidant properties produced in various parts of the plant was responsible to reduce its potential. This was the reason the tender leaves were recorded as superior in comparison to mature leaves. A similar trend was also observed in flowers and seeds. Pakade et al., 2013 observed superior antioxidant properties of the *Moringa oleifera* plant in leaves and flowers. Wangcharoen and Gomolmanee (2011) also reported similar results in their experiment with this plant.

Table 1: Antioxidant properties (µM Eq. Trolox/g) of various organs of *Moringa oleifera* plant collected from various Indian locations

Organ and locations	Flower	Tender leaves	Mature leaves	Seed	Overall
Gwalior	27.40±0.29	22.95±0.16	20.11±0.29	9.99±0.06$^{\#}$	20.11±0.48
Jaipur	28.20±0.28$^{\$}$	23.36±0.23	20.47±0.22	10.04±0.16	20.52±0.49
Dehra Dun	25.38±0.39	25.72±0.22	20.23±0.17	10.26±0.07	20.40±0.47
Overall	26.99±0.21^{a}	24.01±0.16^{a}	20.27±0.13^{b}	10.10±0.06^{c}	20.34±0.28

P-Values: Organs 0.00, Location 0.05 & Interaction, 0.00, $^{\$}$ Higher figure & $^{\#}$ Lower figure.
^{a,b,c}-Values bearing different superscripts within the row differed significantly i.e. P<0.05.

Antioxidant properties (µM Eq. Trolox/g) of various organs of the *Moringa oleifera* plant collected during different seasons along with their interaction have been presented in Tables 2 and 3. The antioxidant properties remained nonsignificant (P>0.05) at three Indian locations viz. Gwalior, Jaipur, and Dehra Dun. The interaction in this regard between the organs of the plant and the month of sample collection was nonsignificant (P>0.05). The reason for such types of findings could be perhaps because the climatic conditions in various calendar months of the year were not very different. The results could not be verified because of the scanty literature in this regard.

Antioxidant properties (µM Eq. Trolox/g) of various organs of the *Moringa oleifera* plant collected during different seasons along with their interaction have been presented in Tables 1 and 3. The antioxidant properties were significantly higher (P<0.05) during January in comparison to that June. The interaction in this regard between three locations and the month of sample collection was nonsignificant (P>0.05). The weather records of three locations reported that the average environmental temperature was lowest and relative humidity highest in January and environmental temperature highest and relative humidity lowest in June in the year 2021-22. Thus, it was indicated that the antioxidant properties increased with the decrease in the environmental temperature and the increase in the relative humidity. The results could not be confirmed because the information in the literature was deficient in this regard.

The interaction between three locations of sample collection, four organs of *Moringa oleifera,* and 12 months of the sampling remained nonsignificant (P>0.05).

Based on interaction data between various parts of the tree and locations of collection, the flowers collected from Jaipur had superior, and seeds from Gwalior had inferior antioxidant properties. Flowers and tender leaves were better compared to mature leaves and seeds and the month of January was the better and June poor season to yield antioxidant properties in the plant.

Table 2: Antioxidant properties (µM Eq. Trolox/g) of various organs of *Moringa oleifera* plant collected during different seasons

Organs and months	Flower	Tender leaves	Mature leaves	Seed	Overall
Jan	27.76±0.76	24.69±0.56	20.84±0.47	10.39±0.22	20.92±0.99^{x}
Feb	27.48±0.75	24.44±0.55	20.63±0.46	10.29±0.22	20.71±0.98^{xy}
Mar	27.20±0.75	24.20±0.55	20.42±0.46	10.18±0.21	20.50±0.97^{xy}
Apr	26.65±0.73	23.70±0.53	20.01±0.45	9.98±0.21	20.08±0.95^{xy}
May	26.09±0.72	23.21±0.52	19.59±0.44	9.77±0.21	19.67±0.93^{xy}
Jun	25.82±0.71	22.96±0.52	19.38±0.43	9.66±0.20	19.46±0.92^{y}
Jul	26.37±0.72	23.46±0.53	19.80±0.44	9.87±0.21	19.87±0.94^{xy}
Aug	26.93±0.74	23.95±0.54	20.22±0.45	10.08±0.21	20.29±0.96^{xy}
Sep	27.20±0.75	24.20±0.55	20.42±0.46	10.18±0.21	20.50±0.97^{xy}
Oct	27.34±0.75	24.32±0.55	20.53±0.46	10.24±0.22	20.61±0.98^{xy}
Nov	27.48±0.75	24.44±0.55	20.63±0.46	10.29±0.22	20.71±0.98^{xy}
Dec	27.62±0.76	24.57±0.55	20.74±0.47	10.24±0.21	20.79±0.99^{x}
Overall	26.99±0.21^{a}	24.01±0.16^{a}	20.27±0.13^{b}	10.10±0.06^{c}	20.34±0.28

P-Values: Organs 0.00, Months 0.00 & Interaction 1.00.
^{a,b,c}-*Values bearing different superscripts within the row differed significantly i.e. P<0.05.*
^{x,y}-*Values bearing different superscripts within the column differed significantly i.e. P<0.05.*

Table 3: Antioxidant properties (µM Eq. Trolox/g) of *Moringa oleifera* plant collected during different seasons from various Indian locations

Months and locations	Gwalior	Jaipur	Dehra Dun	Overall
Jan	20.68±1.74	20.30±1.61	21.78±1.88	20.92±0.99^{x}
Feb	20.47±1.72	20.96±1.81	20.70±1.67	20.71±0.98^{xy}
Mar	20.27±1.71	20.75±1.79	20.49±1.66	20.50±0.97^{xy}
Apr	19.85±1.67	20.33±1.75	20.07±1.62	20.08±0.95^{xy}
May	19.44±1.64	19.90±1.72	19.65±1.59	19.67±0.93^{xy}
Jun	19.23±1.62	19.69±1.70	19.44±1.57	19.46±0.92^{y}
Jul	19.65±1.65	20.12±1.74	19.86±1.60	19.87±0.94^{xy}
Aug	20.06±1.69	20.54±1.77	20.28±1.64	20.29±0.96^{xy}
Sep	20.27±1.71	20.75±1.79	20.49±1.66	20.50±0.97^{xy}
Oct	20.37±1.71	20.86±1.80	20.59±1.66	20.61±0.98^{xy}
Nov	20.47±1.72	20.96±1.81	20.70±1.67	20.71±0.98^{xy}
Dec	20.58±1.73	21.07±1.82	20.72±1.71	20.79±0.99^{x}
Overall	20.11±0.48	20.52±0.49	20.40±0.47	20.34±0.28

P-Values: Locations 0.05, Months 0.00 & Interaction 1.00.
^{x,y}-*Values bearing different superscripts within the column differed significantly i.e. P<0.05.*

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A review of the effects of phosphorus and sulphur levels on growth, yield, and quality of blackgram

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Abstract

The paper reviewed the research work on the effects of phosphorus and sulphur levels on growth, yield, and quality of grams and beans published during 2011-2022. Most of the studies concluded that the levels of phosphorus and sulphur administration influenced the growth, yield, and quality of black gram significantly. The studies compared growth, production, and economic parameters to a valid conclusion. However, the findings varied from study to study but most of the authors showed similar trends. The recommended dose of phosphorus and sulphur for black gram varied for different agroclimatic zones, seasons, soil types and varieties.

Keywords: Black gram, Growth, Phosphorus, Quality, Sulphur, Yield.

Introduction

Blackgram (*Vigna mungo.* L) is one of the most cultivated pulse crops in India. It is popularly known as 'Urd Bean'.Blackgram belongs to the family Leguminoceae. In India, the crop is sown in every season viz. Kharif, Rabi, and summer seasons. Black gram is considered to be one of the cheapest sources of protein. The colour of the seeds varies from black, dark brown, green. *Vigna mungo* commenced from central Asia and India from where it was domesticated. It is found in many tropical zones of Asia, Africa, and Madagascar. Based on geography, India is one of the largest producers of black gram accounting for more than 70% of the global production. After Myanmar and Thailand, India ranks next to these countries. India is the world's largest producer as well as consumer of black gram. It produces about 1.5 to 1.9 million tonnes of black gram annually from about 3.5 million hectares of area, with average productivity of 500 kg per hectare. Black gram accounts for about 10% of India's total pulse production**.** In India Madhya Pradesh, Uttar Pradesh and Andhra Pradesh are the major black gram growing states area-wise. The highest yield was recorded by the state of Bihar (898 kg/ha) followed by Sikkim (895 kg/ha) and Jharkhand (890 kg/ha). The national yield average is 585 kg/ha. Black gram occupies an area of 35.53 lakh hectares with a production of 19.64 lakh tonnes and a productivity of 553 kg/ha. In Madhya Pradesh, black gram is grown in an area of 17.52 lakh hectares with a production of 8.85 lakh tonnes and productivity of 500 kg/ha (GOI 2020). In the Gwalior district, black gram occupies an area of 5.07 thousand hectares with a production of 1.54 thousand tonnes and productivity of

303kg/ha during the year (GOI 2020). Sulphur is one of the essential nutrient elements required for growth and development. Irrespective of crops, sulphur is now called the fourth major plant nutrient. Sulphur is necessary for protein production and activation of enzymes. Sulphur deficiency is mostly caused in coarse-textured soils (Pasricha and Aulakh 1986). Some of the reasons that lead to sulphur deficiency are, the increased removal of sulphur by a crop, high yielding fertilizer crop varieties, increased cropping intensity, and extensive use of sulfur-free fertilizers. The application of sulphur helps to improve the growth, nutrient uptake, grain quality, and yield of black grams (Singh and Aggarwal 1998). To maintain the quality of grains the role of sulphur and phosphorous is important. Sulphur and phosphorous are very essential to increase higher yields. Black gram, being a pulse crop, Black gram requires a high amount of phosphorus (P). Phosphorus is one of the essential macronutrients required for plant growth and development. Phosphorous maintains a role in photosynthesis, metabolism of sugars, energy storage and transfer, cell division, flower formation, cell enlargement, transfer of genetic information, root growth, seed production, nodulation, early crop maturity in plants. Phosphorous acts as an "energy unit" within the plants and helps in root development. The application of some quantity of Phosphorous fertilizers would be essential to sustain the high yield of crops. Phosphorus participates in the process from the starting of seedling growth to seed formation and maturity. It may lead to leaching if Phosphorous is not absorbed by the plant roots. Phosphorous fertilization in legume crops can be used in areas having an adequate amount of water-soluble sulphur. Legume crops usually require an almost equal proportion of sulphur and phosphorous. When sulphur content in the soil was below the critical limit both the growth and quality of the plant were adversely affected. The majority of these enzymes are of great importance in the transformation of energy in the carbohydrate metabolism and respiration of plants.

Effects of Phosphorus levels on growth, yield, and quality of black gram

Patil et al (2011) conducted a field experiment at Parbhani (Maharashtra) consisting of four levels of P_2O_5 (0, 25, 50, and 75 kg P_2O_5 ha^{-1}) and revealed that application of P_2O_5 at 50 kg P_2O_5 ha^{-1} significantly increased the growth of green gram over 25 kg P_2O_5 ha^{-1} and control but at par with 75 kg P_2O_5 ha^{-1}. Patil et al (2011) conducted an experiment on the green gram at Marathwada Agricultural University, Parbhani to conclude that the application of P_2O_5 @ 50 kg ha^{-1} was optimum to harvest the highest yield of green gram. Thenua and Ravindra (2011) conducted a field experiment on chickpeas in sandy loam soil at Lakhota. Results revealed that the application of 60 kg P_2O_5 ha^{-1}, recorded a higher plant height (59.6 cm) and the number of branches per plant (6.3) compared to the control (52.2 cm, 5.8, respectively).

Singh et al (2012) reported that the application of 75 kg P_2O_5 ha^{-1} recorded the maximum plant height, branches per plant, dry matter production per plant, chlorophyll content, leaf area, LAI, grain yield, stalk yield, biological yield, and harvest index, which were significantly superior over 25 kg P_2O_5 ha^{-1} and control (without P_2O_5 application) but at par with 50 kg P_2O_5 ha^{-1} during both the years of experiment. Among the bio inoculants, dual inoculation of PSB + PGPR significantly increased higher growth attributes such as plant height, branches plant, dry matter production, chlorophyll content, leaf area, LAI, grain yield, stalk yield, biological yield, and harvest index.

Akter et al (2013) experimented at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh from December 2008 to April 2009 to evaluate the effect of P (0, 15, 30, 50 kg P_2O_5 ha^{-1}) and S (0, 10, 20, 40 kg S ha^{-1}) and their interaction on the growth and yield of soybean (Glycine max L.) and found highest plant height of soybean with 40 kg S ha^{-1} which was statistically at par with that of 20 kg S ha^{-1}.

Kokani et al (2014) found that P_2O_5 applied 40 kg ha^{-1} on summer black gram significantly increase the plant height at 60 DAS and harvest, number of branches, number of pods per plant, number of seeds per pod, length of the pod, grain (1171 kg ha^{-1}) and stover (2667 kg ha^{-1}) yields as well as protein yield (232.10 kg ha^{-1}) of black gram. Gajera et al (2014) reported that the use of 60 kg P_2O_5 ha^{-1}significantly increased the growth parameters, plant height, branches per plant, dry weight of nodules, leaf area index, and dry matter accumulation as well as yield attributes like the number of pods per plant, grain yield per plant, stover yield and test weight as compared to 40 kg P_2O_5 ha^{-1}. Kokani et al (2014) found the use of 40 kg P_2O_5 ha^{-1}. Significantly increased the plant height, number of branches per plant, number of pods per plant, number of seeds per pod, length of the pod, grain yield of stover yield of summer green gram over control.

Kadam et al (2015) revealed that the use of 40 kg P_2O_5 ha^{-1} on summer green gram significantly increased the plant height, number of leaves, number of branches, and aerial dry matter per plant. Further increase in P_2O_5 level resulted in decreased growth rate indicating that the optimum dose of P_2O_5 for summer green gram was 40 kg ha^{-1}. Singh et al (2015) stated a certain use of 40 kg P_2O_5 enhanced significantly higher no. of seed per pod, no. of pods per plant, no. of nodules, test weight, seed yield, and a further increase in P level fail to produce a significant effect on their indices.

Das (2017) observed that with the application of P_2O_5 a higher number of active nodules were recorded with 60 kg P_2O_5 ha^{-1} at 45 DAS in green gram. Due to the role of P_2O_5 in root development and proliferation which ultimately led to the development of more nodules. Khan et al (2017) reported that the use of 45 kg P_20_5 ha^{-1} significantly increased the dry weight at all stages of 40 and 55 days after sowing than the 40 and 60 kg P_2O_5 ha^{-1}. Patel et al (2017) observed that the higher doses of P_2O_5 (40 kg ha^{-1}) recorded a significantly maximum number of nodules per plant in Kharif green gram. Higher levels of P_2O_5 recorded better growth which facilitated more area for nodule formation. Venktarao et al (2017) stated that the use of 40 kg Phosphorus per hectare on summer green gram recorded the highest no. of total and effective nodules per plant, plant height, and LAI.

Effects of sulphur levels on growth, yield, and quality of black gram

Najar et al (2011) observed that the application of 40 kg S ha^{-1} recorded the highest total N, P, K, S, Ca, and Mg uptake by soybean under temperate conditions in the Kashmir valley. However, the highest S -use efficiency and apparent S recovery were recorded with 10 kg S ha^{-1}, followed by 20 kg S ha^{-1}. The maximum N:S, K:S, Ca:S and Mg:S ratio was recorded under the control, whereas the minimum with the application of 40 kg S ha^{-1} in Stover and seed of soybean. Nawange et al (2011) observed that growth parameters viz., plant height (38.34 cm), the number of branches per plant (5.13), and the number of root nodules per plant (60.50) increased significantly with increasing levels of S up to 40 kg ha^{-1} in chickpea under a medium black clay loam soil at Bhopal. Patil et al (2011) conducted an experiment on the green gram at Marathwada Agricultural University, Parbhani to 18 conclude that the application of S 40 kg ha^{-1} was optimum for the growth and yield of green gram. Prajapati et al (2011) observed that application of S up to 30 kg ha^{-1} in mung bean sole and intercropped with sesame significantly increased the number of pods per plant, seeds per pod, and seed and straw yield of mung bean. Trivedi et al (2011) Application of 40 kg S ha^{-1} gave the highest shoot height, root length, number of leaves per plant, number of pods per plant, length of pods, 100 seed weight, and seed protein content in soybean over control. Thenua and Ravindra (2011) observed a field experiment on chickpea in sandy loam soil at Lakhota. Results revealed that the application of 80 kg S ha^{-1} recorded a higher plant height (58.2 cm) and the number of branches per plant (6.4) compared to the control (50.5 cm and 5.6, respectively).

Bairwa et al (2012) observed that, among different levels of S, 45 kg S ha^{-1} gave significantly higher grain yield (743 kg ha^{-1}) and stover yield (1225 kg ha^{-1}) of a green gram over their respective preceding levels (0, 15 and 30 kg S ha^{-1}) on a pooled basis. Kumar et al (2012) observed that increasing levels of S enhanced the growth, plant height, and yield attributes like number of nodules per plant, dry weight of nodules, number of pods per plant, Number of grains per pod, 1000-grain weight, grain yield, and straw yield showed a maximum increase at 30 kg S ha^{-1} respectively. The increase in grain and straw yield with successive increases in S levels was more at 30 kg S ha^{-1}. Overall, the difference between 20 kg and 30 kg S ha^{-1} did not differ significantly.

Murari Lal et al (2013) experimented on chickpea in sandy clay loam soil at Udaipur. Application of 45 kg S ha^{-1} significantly increased the protein content (23.65%) over control (19.86%) and the rest of the doses. Murari Lal et al (2013) experimented on chickpea in sandy clay loam soil at Udaipur. The application of 45 kg S ha^{-1} significantly increased the grain yield (1854 kg ha^{-1}) compared to the control (1134 kg ha^{-1}) and the rest of the doses.

Bera and Ghosh (2015) stated that the use of 60 kg S per hectare on summer green gram undoubtedly increases the plant height, branches, nodules per plant, and grain output than the low amount of 20, 40 kg S per hectare.

Goswami and Singh (2016) found that the use of 25 kg S ha^{-1} on summer green gram enhanced the plant height, branches per plant, pod per plant, grain per pod, and grain output than the control.

Kudi et al (2018) reported that the use of 30 kg S per hectare on summer green gram enhanced the plant height, branches per plant, number of leaves per plant, number of pods per plant, grains per pod, grain yield than the lower dose 15 kg S ha^{-1}.

Singh et al (2019) experimented at CCS Haryana Agricultural University Krishi Vigyan Kendra, Ambala during the summer season of 2014 to study the effect of P_2O_5 levels and varieties on growth, and yield parameters, yield, economics, and nutrient uptake of green gram. Two varieties of green gram viz. MH 421 and SML 668 and four P_2O_5 levels viz. control (no fertilizer), 20, 40, and 60 kg P_2O_5 ha^{-1} were tested. Cv. MH421 produced significantly higher seed yield (1158 kg ha^{-1}), yield attributing parameters, harvest index, attraction index, net returns (Rs 21001 ha^{-1}), B-C ratio (1.60), and nutrient uptake compared to SML 668 during the summer season. Application of 40 kg P_2O_5 ha^{-1} registered significantly higher seed yield (1283 kg ha^{-1}), yield attributing characters, harvest index, attraction index, net returns (Rs 32351 ha^{-1}), B-C ratio (2.08), and nutrient uptake of green gram compared to control and 20 kg P_2O_5 ha^{-1}. However, 40 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} were at par with the others.

Kumar and Mehra (2022) experimented with different levels of potassium and S the treatment with potassium at 20 kg ha^{-1} and S at 30 kg ha^{-1} produced significantly highest plant height (51.63 cm), a higher number of nodules (29.46), dry weight per plant (25.05 g), highest crop growth rate (12.56), the highest number of pods per plant (45.74), number of seeds per pod (1.88), seed yield (2.03 t ha^{-1}), stover yield (4.45 t ha^{-1}), and Harvest index (31.29%). However, the treatment with potassium at 20 kg ha^{-1} and S at 30 kg ha^{-1} was found to be effective in the highest gross return (1,23,260.4 INR ha^{-1}), net return (87,830.4 INR ha^{-1}), and Benefit-cost ratio (2.47) when compared to the other treatments.

Effects of interaction effects of phosphorous and sulphur levels on growth, yield, and quality of black gram

Jitendra Kumar (2011) studied the effect of graded levels of P_2O_5 (0, 20, 40, and 60 kg ha^{-1}) and S (0, 20, and 40 kg ha^{-1}) on the growth and yield of garden pea applied through SSP and gypsum, respectively. Application of 60 kg P_2O_5 ha^{-1} produced the highest mature green pod yield (73.83 q ha^{-1}). Similarly, the levels of S up to 40 kg ha^{-1} showed a linear increase in plant height, nodulation, and yield of a garden pea. The 23 applications of 40 kg S produced the highest yield (66.51 q ha^{-1}) in sandy loam soil. Tripathi et al. (2011) conducted a field experiment during Kharif 2006 and 2007 at Kanpur to evaluate the response of genotypes of urdbean (*Vigna mungo* L.) to S fertilization in an Inceptisol. Application of S at 25 and 50 kg S ha^{-1}. Uptake of N, K, and S both in grain and Stover increased significantly with increasing levels of S but P_2O_5 uptake was at par with 25 and 50 kg S ha^{-1}. Yadav (2011) conducted a trial at Udaipur to study the effect of P and S on the yield and quality of cluster beans with three levels of P (10, 20, and 40 kg P_2O_5 ha^{-1}) and three levels of S (0, 10, and 20 kg S ha^{-1}). The results indicated that grain and stover yield was increased with an increase in the level of P and S individually as well as in various combinations.

Akter et al (2013) also reported the significant combined effect of different doses of P and S fertilizers on the number of pods per plant in soybean. They recorded the highest number of pods per plant (30.73) with the combined application of 30 kg P ha^{-1} and 40 kg S ha^{-1}. On the other hand, the lowest number of pods per plant (13.00) was recorded at 11 in the P_0S_0 treatment combination.

Kokani et al (2014) conducted a field experiment during the summer of 2013 at the college farm, Navsari Agricultural University, Navsari to study the response of summer black gram (*Vigna mungo* L.) to FYM, P_2O_5, and S. The plant height at harvest (36.73 cm), the number of branches (5.02), seed yield (1149 kg ha^{-1}), and Stover yield (2652 kg ha^{-1}) of black gram was produced significantly higher under the incorporation of 5 t FYM ha^{-1} over control, which was 10.16 and 19.08 per cent higher over control, respectively. Significantly the higher plant height at harvest (37.38 cm), number of branches (5.18), number of pods per plant (20.68), number of seeds per pod (6.26), length of the pod (4.74 cm), grain yield (1171kg ha^{-1}) and Stover yield (2667 kg ha^{-1}) were obtained with the application of 40 kg P_2O_5 ha^{1} over control. Application of S at 20 kg ha^{-1} was also recorded as significantly highest plant height at harvest (37.07 cm), number of branches (5.17), number of pods per plant (20.93), number of seeds per pod (6.30), grain (1153 kg ha^{-1}) and Stover yield (2548 kg ha^{-1}) over control, respectively. Singh et al (2014) conducted a field experiment at Research Farm of BHU, Varanasi to investigate the effect of P x S application on mung beans in sandy loam soil with four levels of P_2O_5 i.e., 0, 15, 30, and 45 kg P ha^{-1} and three levels of S i.e., 0, 10, and 20 kg S ha^{-1} and concluded that mung bean responds well to

PXS fertilization and improves the productivity and the quality of the seeds.

Das et al (2018) Experimental results revealed that yield attributing characters, yield, and protein content of chickpea were significantly influenced by FYM, P_2O_5, S, and interaction effects of these three factors. Application of 60 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} S in a Farmyard manure treated plot (5 t ha^{-1}) along with a recommended dose of nitrogen and potassium proved to be the best treatment combination for increasing the productivity of chickpea and thereby increasing the pulse production of the country.

Das (2017) conducted a field experiment during pre-Kharif 2010, 2011, and 2012 to study the effects of P_2O_5 and S on yield parameters, yield, nodulation, and nutrient uptake of green gram. The experiment was laid out in a factorial randomized block design with three replications having eight treatment combinations viz. four levels of S (0, 20, 40, and 60 kg ha^{-1}) as factor A and two levels of phosphorous (30 and 60 kg ha^{-1}) as factor B. Application of 60 kg P_20_5 ha^{-1} and 40 kg S ha^{-1} proved to be most economic in green gram with NPV 4.59. Singh (2017) conducted a field experiment during the summer season of 2015 at the Crop Research Centre of the Department of Agriculture, Mata Gujri College, Sri Fatehgarh Sahib to study the response of P_2O_5 and S on yield, yield attributes, Number of pods per plant, number of grains per pod, Pod length (cm), 100-grain weight (g), Grain yield (q ha^{-1}), Stover yield (q ha^{-1}), Biological yield (q ha^{1}) and Harvest index (%) nutrient uptake, net returns, and B-C ratio of summer mung bean. The maximum cost of cultivation (Rs28930), net return (Rs38210), and B-C (2.32) ratio were computed under $P_{60}S_{40}$ followed by all other treatment combinations. Singh and Nariya (2017) observed that the dry matter accumulation increased significantly with the progressive increase in P_2O_5 levels up to 60 kg ha^{-1} at 45, 60, 75, and 90 DAS and harvest. An increasing level of P_2O_5 up to 60 kg P_2O_5 ha^{-1} significantly resulted in P_2O_5 and S content and uptake by stover. Further total uptake of nitrogen, potassium and S by chickpea crop was significantly influenced by increasing levels of P_2O_5 up to 60 kg P_2O_5 ha^{-1} and total P_2O_5 uptake by crop was significantly higher with the application of 40 kg P_2O_5 ha^{-1}.

Phogat et al (2020) revealed the utmost concentration and uptake of P_2O_5 in seed (0.376% and 3.59 kg ha^{-1}) and stover (0.266% and 6.38 kg ha^{-1}) and S in seed (0.397% and 3.79 kg ha^{-1}) and stover (0.134% and 3.21 kg ha^{-1}) with the combined application of P_2O_5 60 kg and S 30 kg ha^{-1}, indicating a synergistic effect of P_2O_5 and S on nutrient uptake, respectively. Singh et al (2020) experimental findings revealed that the treatment T_6 (P at 40 kg ha^{-1} + S at 30 kg ha^{-1}) recorded maximum plant height (32.77 cm), number of nodules per plant (18.56), dry weight (11.92 g $plant^{-1}$), crop growth rate (0.703g m^{-2} day^{-1}), number of pods per plant (24.51), number of grains per pod (6.40), test weight (47.60 g), grain yield (2.76 t ha^{-1}) and protein content (24.28%). However, the maximum stover yield (6.22 t ha^{-1}) was obtained with the treatment T_5 (P at 40 kg ha^{-1} + S at 25 kg ha^{-1}). Maximum gross return (Rs 124200 ha^{-1}), net return (Rs 82422.58 ha^{-1}), and B-C ratio (2.97) were recorded with the treatment T_6 (P at 40 kg ha^{-1} + S at 30 kg ha^{-1}).

Sahu et al (2021) observed that application at 60 kg P_2O_5 ha^{-1} being statistically at par with 40 kg ha^{-1} P_2O_5 registered more growth parameters and yield attributes than the lower levels. The seed yield (1079.6 kg ha^{-1}) and stover yield (2025.1 kg ha^{-1}) were also noted with the application of 60 kg P_2O_5 ha^{1} and it remained statistically at par with 40 kg P_2O_5 ha^{-1}. However, 30 kg S ha^{-1} being statistically at par with 45 kg S ha^{-1} resulted in superior growth attributes, yield parameters, and seed (979.2 kg ha^{-1}) and stover yield (1871.8 kg ha^{-1}) to lower levels. Further, the combination of 60 kg P_2O_5 ha^{-1} and 30 kg S ha^{-1} produced significantly more grain yield (1211.3 kg ha^{-1}) than other treatment combinations. The study concludes that rabi green gram can be grown with 60 kg P_2O_5 and 30 kg S ha^{-1} for better productivity.

Chaudhari et al (2022) conducted a field experiment in randomized block design, the treatments comprised three levels of P_2O_5 (20, 40, and 60 kg P_2O_5 ha^{-1}) as one factor and three levels of S (20, 40, and 60 kg S ha^{-1}) as another factor. The results revealed that an application of 60 kg P_2O_5 ha^{-1} recorded significantly higher P_2O_5 content in seed as well as stover and S content in stover, higher uptake of nitrogen, P_2O_5, potassium, and S by seed as well as stover. An application of 60 kg S ha^{-1} recorded significantly higher S content in seed as well as stover, uptake of nitrogen, P_2O_5, potassium, and S by seed and stover. The interaction effect of 40 kg P_2O_5 ha^{-1} + 60 kg S ha^{-1} recorded significantly higher P_2O_5 and S uptake by the seed of green gram.

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Effect of tillage, FYM, and mulch on soil physicochemical properties in Hamelmalo Region, Eritrea

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Abstract

Land degradation and water conservation are serious problems in Eritrea, hence to arrest degradation and conserve water, a field experiment was conducted in the watershed area of Hamelmalo Agricultural College, Keren, Eritrea during the summer season of 2018 intending to study the effect of tillage, FYM, and mulch on soil physicochemical properties with sorghum crop, under rainfed conditions. A split-split plot experimental design was chosen with tillage (conventional tillage, CT; reduced tillage, RT and no-till, NT) as the main plot, FYM (0, 5, 10, 15 t ha^{-1}) as sub-plot and mulch (0, 4 t ha^{-1}) as sub-sub-plot in three replications. Each sub-sub-plot was 15 m^2. The plots were bunded to avoid any run-off, in or out. The distance between subplots and sub-sub plots was 40 cm. Results showed that tillage affected infiltration rate and bulk density and FYM bulk density, and infiltration rate, positively influenced soil aggregation and soil chemical properties significantly ($p<0.05$). The highest mean weight diameter was observed in NT (6.12 mm), and the lowest was in CT (2.8 mm). Soil organic matter was highest in NT with 15 t ha^{-1} FYM, which elevated the organic matter content of the soil by 62 % as compared to pre-sowing. Phosphorus level in soil improved from very low to low in 15 t ha^{-1} FYM with mulch over 0 t ha^{-1}. FYM of 15 t ha^{-1} with Mulch brought a slight change in exchangeable cations (Na, K, Ca, and Mg).

Keywords: Farmyard manure, Mulch, Soil, Physico-chemical properties, Tillage.

Introduction

In Eritrea, high rainfall intensities, steep slopes, shallow soils, and poor ground cover result in high runoff and soil loss; with the disappearance of the topsoil and exposure of the compacted subsoil which would worsen land degradation. Soil and water management techniques are not effectively put into practice or utilized due to a host of factors including insecure land tenure system, weak agricultural extension services, low educational level of farmers, lack of confidence in adopting or adapting improved water harvesting and nutrient management measures (Tesfay et al. 2020). Thus, as a result of agroecosystem degradation, the land is unable to retain moisture and hence farmers are unable to harvest acceptable levels of crops even during the normal rainy season. Efforts are needed to develop techniques to increase the infiltration of soil and soil moisture retention capacity in the root zone and management practices such as minimum tillage, mulching, and application of farmyard manure can contribute almost in all aspects of soil quality and fertility. Soil biota increased under mulched soil environment thereby improving nutrient cycling and organic matter build-up for several years (Holland 2004). Low soil fertility is one of the most severe constraints to smallholder crop production and to sustain food security in dry lands (Alemu and Bayo 2005); to improve the fertility of the soil, incorporation of Farmyard Manure (FYM) into the soil is an alternative practice in dry land farming.

The present study, therefore, was undertaken to optimize tillage, the use of mulch, and the application of farmyard manure as soil and water management practices to improve the soil physical and chemical properties and fertility with sorghum as a test crop.

Materials and methods

The field experiment was conducted in the Model Integrated Watershed Management site at Hamelmalo Agricultural College (HAC), Keren, Eritrea, 15°52'21" N and 38°27'42" E latitude and longitude, respectively at an elevation of about 1285 m above mean sea level. The study area has a semi-arid climate with an average annual rainfall of 434 mm. Soil physicochemical properties of the experimental field were determined before sowing and after harvest using standard methods and procedures. The results of the physicochemical properties of the composite sample of the area are presented in Table 1.

Table 1: Soil physicochemical properties of the experimental field before sowing

Soil parameters	Value
Sand (%)	55.1
Silt (%)	31.5
Clay (%)	13.5
Textural class	Sandy loam
Bulk density (g cm^{-3})	1.45
Saturated hydraulic conductivity (cm hr^{-1})	4.2
Field capacity (%) by volume (cm^3cm^{-3})	0.27
EC (1:5) (dSm^{-1})	0.07
pH (1:5)	8.26
Organic matter (%)	0.47
Available nitrogen (%)	0.007
Extractable phosphorous (ppm)	2.6
Exchangeable potassium (mol kg^{-1})	0.87
Exchangeable Ca ($cmolkg^{-1}$)	26.3
Exchangeable Mg ($cmolkg^{-1}$)	4.6
Exchangeable Na+($cmolkg^{-1}$)	0.17
CEC (cmolkg-1)	28.4

Soil aggregates were determined as described by Kember and Rosenau (1986). The basic infiltration rate was measured using a double-ring infiltrometer before sowing and after harvesting following the procedure outlined by Brouwer et al. 1988. The saturated hydraulic conductivity (K_s) of soil was determined using the Porchet method.

$$K_s = 1.15r\,(\text{Log}\,(ho+0.5r) - \log\,(ht + 0.5r)/t)$$

Where: K_s = hydraulic conductivity; t = time since the start of measuring (s); ht = the height of the water column in the hole at time t (cm), $h_0 = h_0$ at time t = 0; r = radius of the hole (cm).

The experiment was planned to have three tillage practices: conventional tillage (CT) reduced tillage (RT) and no-till (NT). Land leveling was done carefully to ensure an equal flow of water within the experimental plot except in no-till to avoid soil disturbances.

FYM in t ha^{-1} were; $F_0 = 0$, F_1=5, F_2 = 10, and F_3 = 15
Mulch in t ha^{-1} were; M_0= 0, M_1 = 4

Split-split plot design was used with three replications. Each replication consisted of 24 plots. For convenience tillage was taken as the main plot, FYM as a subplot, and mulch as sub-sub plots. Each sub-subplot had a dimension of 4.0 m x 3.75 m. The plots were bunded, (0.40 m wide and 0.30 m height,) appropriately to avoid any run-off or run-on. The distance between sub-plots and sub-sub plots was 40 cm and the size of replication was 26.8 m×17 m. The gross size of the study area was 80.8 m x 17 m. Sorghum variety [ICSV 210 (Bushika)] was sown at a seed rate of 15 kg ha^{-1}. The seeds were sown in rows 0.75 m apart at an average depth of (0.03 - 0.05) m manually.

The effect of tillage, FYM, and mulch on bulk density, infiltration rate, and saturated hydraulic conductivity, dry soil aggregate, chemical properties of composite soil were estimated. The data obtained from all the measured parameters of the experiment under various treatments were subjected to statistical analysis (Snedecor and Cochran, 1994) using the GEN STAT software (12th ed) and the treatment means were compared with Least Significant Difference (LSD) at a 5 per cent level of probability.

Results and discussions

Tillage showed a statistically significant difference in soil bulk density (BD) at harvest, p<0.05 (Table 2); perhaps because tillage disturbed soil particles and increased its volume as compared to non-plowed soils in the upper 10 cm depth. Hence, the highest (1.44 Mg m^{-3}) and lowest (1.34 Mg

Table 2: The effect of tillage, FYM, and mulch on bulk density, infiltration rate, and saturated hydraulic conductivity (cm hr^{-1})

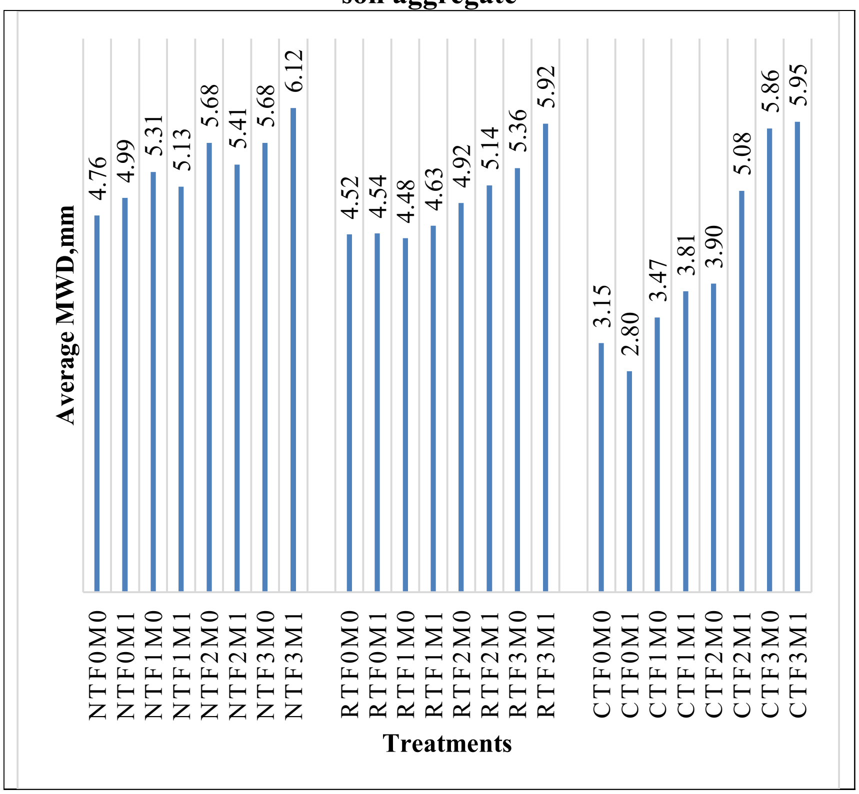
Treatments	BD Mgm^{-3}	IR cm hr^{-1}	Ks cm hr^{-1}
NTF_0M_0	1.53	3.23	4.43
NTF_0M_1	1.44	4.23	5.23
NTF_1M_0	1.46	5.20	5.43
NTF_1M_1	1.44	6.20	4.10
NTF_2M_0	1.40	7.07	4.40
NTF_2M_1	1.37	6.73	5.03
NTF_3M_0	1.42	7.57	4.70
NTF_3M_1	1.45	8.47	5.20
RTF_0M_0	1.41	4.00	3.93
RTF_0M_1	1.37	4.07	4.33
RTF_1M_0	1.37	6.53	4.97
RTF_1M_1	1.35	5.13	4.40
RTF_2M_0	1.38	6.40	4.83
RTF_2M_1	1.44	7.00	4.67
RTF_3M_0	1.39	7.80	5.07
RTF_3M_1	1.36	8.60	4.13
CTF_0M_0	1.37	4.27	3.70
CTF_0M_1	1.36	5.40	4.00
CTF_1M_0	1.32	6.67	4.53
CTF_1M_1	1.31	6.60	3.70
CTF_2M_0	1.36	6.80	4.70
CTF_2M_1	1.33	8.53	4.27
CTF_3M_0	1.31	10.6	5.13
CTF_3M_1	1.31	10.5	5.57
LSD*	NS	NS	NS
CV (%)	2.10	18.3	14.1
Factors	LSD*	LSD*	LSD*
Tillage	0.04	NS	NS
FYM	0.03	1.12	NS
Mulch	0.00	NS	NS

Note: *M_0=0 tha^{-1} and M_1=4 tha^{-1}, F_0=0 ton/ha, F_1=5 t ha^{-1} F_2=10 t ha^{-1} and F_2=15 t ha^{-1}, CT=conventional-tillage, NT=no-tillage and RT=reduced-tillage, BD-bulk density, IR-infiltration rate, Ks-hydraulic conductivity, LSD = Least Significance of Difference and CV = coefficient of variation, *p=0.05.*

m^{-3}) BD after harvest were recorded in NT and CT, respectively. The finding was in agreement with Kashif (2006). Brady (1964) also reported that tillage significantly decreased the bulk density of the upper soil surfaces due to plowing. FYM incorporation into soil reduced soil bulk density. Moreover, increasing the FYM level facilitated the restoration of soil organic matter in the soil which helped to develop soil aggregates, thus increasing the infiltration rate. The highest and lowest BD at harvest was recorded in F_0, and F_3, respectively; F_1 was at par with F_2. These results were in agreement with Bloom et al. (1999), Kashif (2006), and Majid and Feredoun (2008) work. The perusal of data indicated a statistically significant difference in BD at harvest due to mulch. The decrease in bulk density might be due to mulch which had protected the soil from rainfall impact in comparison to non-mulched. This was in agreement with Kashif (2006) and Brady (1964). The effects of tillage, FYM, and mulch interactions on bulk density were statistically non-significant with the interaction of different treatments; however, a slight numerical decrease was observed, which might be due to the application of FYM and mulch. This finding was in agreement with Bandyopadhyay (2010).

There were statistically significant ($P<0.05$) differences in IR due to FYM application at harvest; Highest and lowest IR were recorded in treatments F_3 and F_0, respectively. The results of the interaction between tillage, FYM, and mulch on IR (cm hr^{-1}) revealed that after harvest, all treatments maintained statistically non-significant differences on the IR with a grand mean value of 6.57 cm hr^{-1}. However, numerically IR was increasing with an increasing rate of FYM and mulch application. The highest and lowest were in CT F_3 M_1 (10.60 cm hr^{-1}) and NT F_0 M_0 (3.23cm hr^{-1}), which was in agreement with Biamah et al. (2003). FYM also enhanced infiltration and reduced soil crusting and compaction.

Figure 1: Effect of tillage, FYM, and mulch interaction on dry soil aggregate



Note: M_0=0 t ha-1 and M_1=4 t ha-1, F_0=0 t ha-1, F_1=5 t ha-1, F_2=10 t ha-1 and F_2=15 t ha-1, CT=conventional-tillage, NT=no-till and RT=reduced-tillage.

There were no significant differences in hydraulic conductivity (Ks) due to tillage.

This could be mainly due to undisturbed porosity in NT and an immediate increase of porosity as a result of tillage in CT only in the upper soil layer which might not have affected the Ks of the profile. The results were in line with the reports of Tesfalem (2016). However, the effect of FYM on saturated hydraulic conductivity was found to be non-significant. The effects of tillage, FYM and mulch interactions were statistically non-significant for Ks in all the plots; however, an increment in hydraulic conductivity rate was observed with the increasing application of FYM, with mulch and tillage. Highest Ks was recorded in CT F_3 M_1 and the lowest in CT F0 M0. This finding was in agreement with Bandyopadhyay (2010) who reported that recommended dose of FYM resulted in a significant ($P < 0.05$) decrease in bulk density and an increase in hydraulic conductivity.

Table 3: Pre-sowing and post-sowing mean chemical properties of composite soil samples

Treatment	pH (1:5)	EC (1:5)	OM (%)	P (ppm)	N (%) avai	Na+ cmol/kg	K+ cmol/kg	Ca++ cmol/kg	Mg++ cmol/kg	CEC (cmol/kg)
Pre-sowing	8.26	0.07	0.47	2.60	0.01	0.17	0.87	26.30	4.60	28.40
Post-sowing										
Tillage										
NT	8.33	0.07	0.68	5.60	0.01	0.17	0.81	24.45	4.90	30.40
RT	8.25	0.06	0.60	7.52	0.01	0.15	0.89	22.98	4.61	28.74
CT	8.20	0.07	0.46	4.23	0.01	0.19	1.00	27.74	5.54	34.30
FYM										
F_0	8.30	0.06	0.35	3.32	0.01	0.17	0.87	26.10	5.20	32.32
F_1	8.27	0.06	0.46	4.76	0.01	0.16	0.83	24.05	4.82	29.90
F_2	8.23	0.07	0.66	6.21	0.01	0.16	0.94	23.88	4.80	29.78
F_3	8.23	0.07	0.85	8.84	0.01	0.20	0.95	26.18	5.25	32.58
Mulch										
M_0	8.26	0.07	0.55	6.16	0.01	0.19	0.91	25.67	5.14	31.93
M_1	8.25	0.06	0.60	5.41	0.01	0.15	0.89	24.44	4.89	30.36
Interaction of FYM *Mulch										
F_0+M_0	8.28	0.07	0.45	4.74	0.01	0.18	0.89	25.88	5.17	32.13
F_0+M_1	8.27	0.06	0.48	4.37	0.01	0.16	0.88	25.27	5.05	31.34
F_1 +M_0	8.27	0.07	0.51	5.46	0.01	0.18	0.87	24.86	4.98	30.92
F_1 +M_1	8.26	0.06	0.53	5.09	0.01	0.15	0.86	24.25	4.85	30.13
F_2+M_0	8.25	0.07	0.60	6.18	0.01	0.17	0.93	24.78	4.97	30.86
F_2+M_1	8.24	0.06	0.63	5.81	0.01	0.15	0.92	24.16	4.85	30.07
F_3+M_0	8.25	0.07	0.70	7.50	0.01	0.20	0.93	25.93	5.20	32.26
F_3+M_1	8.24	0.06	0.72	7.13	0.01	0.17	0.92	25.31	5.07	31.47
Mean	8.26	0.06	0.58	5.78	0.01	0.17	0.90	25.05	5.02	31.15

The effect of tillage, FYM, and mulch interaction on dry soil aggregate is shown in Figure 1. The impact of tillage on soil aggregate decreased with increased FYM dose and with much; while mulch material and FYM led to improvement in soil conditions. The severity of the reduction in soil aggregate was strongly related to soil disturbances mainly because of more disturbed soil without FYM and mulch ranked the lowest in soil aggregation. Therefore, the lowest soil aggregates were observed in CT F_0 M_0. An increase in the application of FYM and mulch improved the soil aggregation conditions. The tillage practices negatively affected soil aggregation, which emphasized the removal of the soil sticking agents of soil aggregates. This result was in agreement with Tesfalem (2016) and Isaac (2008).

Relatively highest (8.30) and lowest (8.22) pH values were recorded in NTF0M0 and CTF3M1, respectively (Tables 3, 4, and 5). Compared with the pre-sowing soil pH (8.26), slight changes were observed in the pH of all treatments might be due to tillage, FYM, and mulch, yet the soil pH of all treatments after harvest remained unchanged at moderate alkaline. Short-term experiments might not bring considerable change in pH. Wagh et al. (2016) reported that a slight change in pH was observed under FYM and no specific trend was observed due to various treatments.

Table 4: Pre-sowing and post-sowing mean chemical properties of composite soil samples

Treatment	pH (1:5)	EC (1:5)	OM (%)	P (ppm)	N (%) avai	Na+ cmol/kg	K+ cmol/kg	Ca++ cmol/kg	Mg++ cmol/kg	CEC (cmol/kg)
Pre-sowing	8.26	0.07	0.47	2.60	0.01	0.17	0.87	26.30	4.60	28.40
Post-sowing of the Interaction of tillage *FYM										
$NT+F_0$	8.31	0.06	0.51	4.46	0.01	0.17	0.84	25.28	5.05	31.36
$NT+F_1$	8.30	0.06	0.57	5.18	0.01	0.17	0.82	24.25	4.86	30.15
$NT+F_2$	8.28	0.07	0.67	5.91	0.01	0.16	0.88	24.17	4.85	30.09
$NT+F_3$	8.28	0.07	0.76	7.22	0.01	0.18	0.88	25.32	5.08	31.49
$RT+F_0$	8.27	0.06	0.47	5.42	0.01	0.16	0.88	24.54	4.91	30.53
$RT+F_1$	8.26	0.06	0.53	6.14	0.01	0.15	0.86	23.51	4.71	29.32
$RT+F_2$	8.24	0.07	0.63	6.87	0.01	0.15	0.91	23.43	4.71	29.26
$RT+F_3$	8.24	0.06	0.72	8.18	0.01	0.17	0.92	24.58	4.93	30.66
$CT+F_0$	8.25	0.06	0.41	3.78	0.01	0.18	0.94	26.92	5.37	33.31
$CT+F_1$	8.23	0.06	0.46	4.50	0.01	0.18	0.92	25.89	5.18	32.10
$CT+F_2$	8.21	0.07	0.56	5.22	0.01	0.17	0.97	25.81	5.17	32.04
$CT+F_3$	8.21	0.07	0.66	6.54	0.01	0.20	0.97	26.96	5.39	33.44
Mean	8.26	0.06	0.58	5.78	0.01	0.17	0.90	25.05	5.02	31.15
Interaction of tillage *Mulch										
$NT+M_0$	8.29	0.07	0.62	5.88	0.01	0.18	0.86	25.06	5.02	31.17
$NT+M_1$	8.29	0.06	0.64	5.51	0.01	0.16	0.85	24.45	4.90	30.38
$RT+M_0$	8.25	0.07	0.57	6.84	0.01	0.17	0.90	24.32	4.88	30.34
$RT+M_1$	8.25	0.06	0.60	6.47	0.01	0.15	0.89	23.71	4.75	29.55
$CT+M_0$	8.23	0.07	0.51	5.19	0.01	0.19	0.95	26.70	5.34	33.12
$CT+M_1$	8.22	0.06	0.53	4.82	0.01	0.17	0.95	26.09	5.21	32.33
Mean	8.26	0.06	0.58	5.78	0.01	0.17	0.90	25.05	5.02	31.15

Highest (0.71%) and lowest (0.46%) values of SOM were recorded in NTF3M1 in CTF0M0, respectively. Both individual and interactive (combined) effects of the given treatments showed a numerical increase in soil organic matter. Out of all the treatments applied, NT+F3 showed a relatively highest increment in SOM, which elevated the organic matter content of the experimental soil by 61.7 % as compared to pre-sowing SOM content. Yet, the organic matter content of the soil after harvest was very low as per Charman and Roper (2007) rating standards of soil chemical properties. Since this result was found from a one-year experiment, long-term experiments might be recommended to achieve optimum organic content.

There was no considerable change in soil electrical conductivity (EC) as affected by the different treatments. The highest value recorded was 0.07 which was the same as the original soil EC, depicting no change in EC despite the applied treatments. The lowest value recorded was 0.06, which showed a slight change as compared to the pre-sowing soil EC. Based on the results of the analysis, it could be concluded that there was no change in soil electrical conductivity due to the applied treatments under the one-year experimental condition. Wagh et al. (2016) reported that a slight change in electrical conductivity was observed under FYM and no specific trend was observed due to various treatments.

Table 5: Pre-sowing and post-sowing mean chemical properties of composite soil samples

Treatment	pH (1:5)	EC (1:5)	OM (%)	P (ppm)	N (%) avai	Na^+ cmol/kg	K^+ cmol/kg	Ca^{++} cmol/kg	Mg^{++} cmol/kg	CEC (cmol/kg)
Pre-sowing	8.26	0.07	0.47	2.60	0.01	0.17	0.87	26.30	4.60	28.40
Post-sowing of the interaction of tillage, FYM, and mulch										
NTF$_0$M$_0$	8.30	0.07	0.53	5.03	0.01	0.18	0.89	25.41	5.08	31.55
NTF$_0$M$_1$	8.29	0.06	0.54	4.78	0.01	0.16	0.88	25.00	5.00	31.03
NTF$_1$M$_0$	8.29	0.07	0.56	5.51	0.01	0.18	0.88	24.72	4.95	30.74
NTF$_1$M$_0$	8.28	0.06	0.58	5.26	0.01	0.16	0.87	24.31	4.87	30.22
NTF$_2$M$_0$	8.27	0.07	0.63	5.99	0.01	0.17	0.91	24.67	4.95	30.71
NTF$_2$M$_1$	8.27	0.06	0.64	5.74	0.01	0.16	0.91	24.26	4.86	30.18
NTF$_3$M$_0$	8.27	0.07	0.69	6.87	0.01	0.19	0.91	25.43	5.10	31.64
NTF$_3$M$_1$	8.27	0.06	0.71	6.62	0.01	0.17	0.91	25.03	5.01	31.11
RTF$_0$M$_0$	8.27	0.07	0.50	5.67	0.01	0.17	0.93	24.91	4.98	31.00
RTF$_0$M$_1$	8.26	0.06	0.52	5.42	0.01	0.15	0.92	24.51	4.90	30.47
RTF$_1$M$_0$	8.26	0.07	0.54	6.14	0.01	0.17	0.91	24.23	4.86	30.19
RTF$_1$M$_1$	8.25	0.06	0.55	5.90	0.01	0.15	0.91	23.82	4.77	29.67
RTF$_2$M$_0$	8.25	0.07	0.60	6.63	0.01	0.16	0.95	24.18	4.85	30.15
RTF$_2$M$_1$	8.24	0.06	0.62	6.38	0.01	0.15	0.94	23.77	4.77	29.63
RTF$_3$M$_0$	8.25	0.07	0.67	7.50	0.01	0.18	0.95	24.94	5.00	31.08
RTF$_3$M$_1$	8.24	0.06	0.68	7.26	0.01	0.16	0.95	24.53	4.92	30.56
CTF$_0$M$_0$	8.25	0.07	0.46	4.57	0.01	0.18	0.86	26.50	5.29	32.85
CTF$_0$M$_1$	8.25	0.06	0.47	4.32	0.01	0.17	0.86	26.09	5.21	32.33
CTF$_1$M$_0$	8.24	0.07	0.49	5.05	0.01	0.18	0.85	25.82	5.17	32.04
CTF$_1$M$_1$	8.24	0.06	0.51	4.80	0.01	0.17	0.84	25.41	5.08	31.52
CTF$_2$M$_0$	8.23	0.07	0.56	5.53	0.01	0.18	0.89	25.76	5.16	32.01
CTF$_2$M$_1$	8.22	0.06	0.57	5.29	0.01	0.16	0.88	25.35	5.08	31.48
CTF$_3$M$_0$	8.23	0.07	0.62	6.41	0.01	0.20	0.89	26.53	5.31	32.94
CTF$_3$M$_1$	8.22	0.06	0.64	6.16	0.01	0.18	0.88	26.12	5.23	32.41
Mean	8.26	0.06	0.58	5.78	0.01	0.17	0.90	25.05	5.02	31.15

There was no difference in available nitrogen level (N) among all the treatments. Available soil nitrogen in the experimental area was very low (Bruce and Rayment 1982). The phosphorous level (P) of the soil before sowing was very low (2.6 ppm), but after harvest, the highest values were recorded in RT (7.52 ppm), F3 (8.8 ppm), M$_0$ (6.16 ppm), RT+F$_3$ (8.18 ppm), RT+M$_0$ (6.84 ppm), F$_3$+M$_0$ (7.50 ppm) and RTF$_3$M$_0$ (7.50 ppm) when all treatments are independently considered. Out of all the different treatments applied, however, the highest increment in P was recorded in F3 and soil P was increased by 238.5 % as compared with the level of soil P before sowing. This might be attributed to the application of FYM, which was rich in phosphorous. The lowest values, on the other hand, were recorded in CT (4.23 ppm), F$_0$ (3.32 ppm), M$_1$ (5.41 ppm), CT+F$_0$ (3.78 ppm), CT+M$_1$ (4.82 ppm), F$_0$+M$_1$ (4.37 ppm) and CTF$_0$M$_1$ (4.32 ppm). When the mean value of all the aforementioned treatments was evaluated, soil P showed an overall increment of 122.3

%. Despite the great increment in soil P after harvest, as compared to the pre-sowing P-level, the current P-level in the soil was still low (Holford and Cullies, 1985; Verde et al. 2013). Therefore, continuous application of the recommended dose of FYM might bring soil P to the optimum level with time.

A slight numerical change was observed in exchangeable cations due to tillage treatment. Highest values were recorded in conventional tillage (CT) for sodium (0.19 cmol/kg), calcium (27.74 cmol/kg), and magnesium (5.54 cmol/kg) and in Reduced Tillage (RT) for potassium (1.0 cmol/kg). Similarly, the application of FYM and mulch brought a slight change in exchangeable cations and the highest values were recorded in F3 0.2 cmol/kg, 0.95 cmol/kg, 25.67 cmol/kg, and 5.25 cmol/kg for Na, K, Ca and Mg, respectively and M_0 0.19 cmol/kg, 0.91 cmol/kg, 25.67 cmol/kg and 5.14 cmol/kg for Na, K, Ca and Mg, respectively for all of the exchangeable cations studied. Similar to the individual treatment, the synergetic effect also showed a numerical but very slight change in exchangeable cations, and the highest values were observed in treatment combinations of CT+F_3, CT+M_0, F_3+M_0, and CTF_3M_0, almost for all the cations considered under this study. The changes observed in exchangeable cations due to the applied treatment were very negligible and this slight change might have a role in improving the levels of these cations for plant nutrition but did not have any negative impact on the soil environment as their level was still low except for Ca rated as very high and Mg high both pre-sowing and after harvest (Metson 1961).

The Cation Exchange Capacity (CEC) of the experimental soil was slightly changed when it was evaluated after harvest under all the treatments applied. Relatively highest values were recorded in CT (34), F_3 (32.58), M_0 (31.93), CT+F_3 (33.4), CT+M_0 (33.12), F_3+M_0 (32.26) and CTF_3M_0 (32.92) in tillage, FYM, Mulch, the interaction between tillage and FYM, between tillage and mulch, between FYM and mulch, and among tillage, FYM, and mulch, respectively. Out of all the treatments applied, the highest CEC was observed in Tillage (CT) followed by a combination of tillage and FYM (CT+F_3) and tillage and mulch (CT+M_0). Though the relative change in CEC was observed in the experimental soil after harvest, the change was negligible as CEC values both pre-sowing and after harvest was under the same rating as per Metson (1961). This current result indicated that short-term experiment was less probable to bring significant change in soil chemical properties.

Conclusions

Interactions of tillage, FYM, and mulch have a positive impact on soil properties. Tillage showed a statistically significant difference in BD at harvest at 0-10 cm depth. Hence conventional tillage was detrimental to the soil's physical properties. Leveled bunded land, no-till with mulch had a less negative impact on soil properties. Application of FYM also had a significant effect on BD, infiltration rate (IR), and soil aggregation at harvest. In addition, all the soil's chemical properties showed improvements.

Recommendations

Continuous application of FYM during tillage practices will have less negative impact on soil physical properties due to tillage practice. To keep soil potentiality and productivity continuous application of FYM is desired. Even the soil nutrient capacity was improved in the first application. These recommendations are based on one-year research, hence to make them more concrete and sounder, the experiment should be repeated.

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Snedecor G W and Cochran W G. 1994. Statistical Methods, 6th edn, 491p. Iowa State University Press, Ames.

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Clark J A and McArthur A J. 1994. Thermal Exchanges. Livestock Housing.1edn, pp. 97-122. (Eds) Wathes C M and Charles D R. CAB INTERNATIONAL, Wallingford, UK. For Symposium Devegowda G, Raju M V L N, Afzali N and Swamy H V L N. 1998. Mycotoxin picture world-wide: Novel solutions for their counteraction. Proceedings of 14th Alltech's Annual Symposium on Biotechnology in the Feed Industry. pp. 241-55. 5 May 1997. Bangalore.

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