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RESEARCH ARTICLE

Influence of foliar applied nitrogen, phosphorus and potassium on the vegetative and reproductive attributes of Roselle *(Hibiscus sabdariffa)*

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Abstract
An experiment was conducted to study the influence of foliar application of nitrogen, phosphorus and potash (NPK) on the vegetative and reproductive attributes of Roselle. The experiment was designed using Randomized Complete Block Design (RCBD) with one factor i.e., NPK treatments (0, 3, 4, 5, 6 g l^{-1}). Treatments were repeated four times. The experiment was carried out in Ornamental Horticulture Nursery, Department of Horticulture, The University of Agriculture, Peshawar during the year 2020. Data were recorded on plant height (cm), stem diameter(mm), number of branches $plant^{-1}$, number of leafs $plant^{-1}$, leaf area(cm^2), days to first flowering, days to last flowering, number of calyces $plant^{-l}$, calyx diameter, calyces fresh weight $plant^{-l}$, pod size, number of seeds pod^{-l} . Foliar application of NPK had significant effect on most of the studied attributes. Maximum plant height (104.75 cm), stem diameter (2.23 mm), number of branches $plant^{-1}$ (13.5), number of leaves $plant^{-1}$ (301), and leaf area (118.25cm^2), minimum days to first flowering (106.50), maximum days to last flowering (128), calyx diameter (27.275 mm), calyces fresh weight $plant^{-1}$(219.88 g), pod size(21.532 mm) and number of seeds pod^{-1} (25.68) were recorded in plants sprayed with NPK @ 6g L^{-1}. Minimum plant height (67.50 cm), stem diameter (0.7775 mm), number of branches (4.000), number of leaves (58.50), and leaf area (113.00cm^2), maximum days to first flowering (109.00), minimum days to last flowering (114.75), calyx diameter (23.835mm), calyces fresh weight $plant^{-1}$ (89.84 g), pod size (19.617mm) and number of seeds (21.688) were recorded in control plants (Sprayed with distilled water). It is concluded that plants treated with foliar applied NPK at 6g L^{-1} improved most of the vegetative and reproductive variables of Roselle and hence could be recommended for better growth and production of Roselle under the agro-climatic conditions of Peshawar.

Keywords: Micronutrient; foliar spray; vegetative attributes; Flowers and seed production

Introduction

Roselle (*Hibiscus sabdariffa* L.) is a herbaceous shrub that belongs to the family *Malvaceae*. It is native to Asia and tropical Africa. The plant is mainly grown in tropics such as Africa, Australia, Brazil, Caribbean, Central America, Florida, India, Hawaii and Philippines (Gautam, 2004). The crop is grown mainly in traditional farming system, mostly under rain fed conditions in many tropical and subtropical countries (Cobley, 1975).

It is mostly grown for attractive edible calyces (Purseglove, 1991). It is known by many names such as ‘Florida roselle’and ‘Florida cranberry’ in Florida, USA; ‘bisap’ in Senegal and ‘Sobo’ in Nigeria (Wong *et al.*,2002).The warm and humid tropical climate is suitable for Roselle plants as it is exceptionally susceptible to frost and mist (Ahmed *et al.*,1981). Roselle can be growth best in areas with temperature ranges from 18 to 35ºC, with an optimum of 25ºC. Growth of the plant ceases at 14ºC (Mc-Clintock *et al*., 2004). The plant grows well in most of the soils but it should be well-drained. It can tolerate poor soils as well and is often grown as a supplementary rather than primary crop (Hacket and Carolene, 1982).

Hibiscus sabdariffa is an annual, erect, bushy, herbaceous shrub that can grow up to 8 ft (2.4 m) tall, with smooth or nearly smooth, cylindrical, typically red stems. The leaves are alternate, 3 to 5 in (7.5–12.5 cm) long, green with reddish colour veins and long or short petioles. The leaves of young seedlings and upper leaves are simple; lower leaves are deeply 3 to 5 or even 7 lobed; the margins are toothed. Flowers, borne singly in the leaf axils, are up to 12.5 cm wide, yellow or buff with a rose or maroon eye, and turn pink as they wither at the end of the day. At this time, the typically red calyx, consisting of 5 large sepals with a collar (epi-calyx) of 8 to 12 slim, pointed bracts (or bracteoles) around the base, begins to enlarge, becomes fleshy, crisp but juicy. The capsule turns brown and splits open when mature and dry. The calyx, stems and leaves are acidic in nature and closely resemble with the cranberry in flavor (Morton, 1987; Ross, 2003).

Roselle is a short-day plant that is very sensitive to the photoperiod. In the first 4-5 months of its growth, Roselle requires a daily light phase of 13 hours (Mc-Clintock *et al.,* 2004). Roselle plants prefer well-drained, humus and rich-fertile soils with a pH of 5.5 to 8.0 (Augstburger, 2009). Roselle is resistant to relatively high temperatures throughout the growing and fruiting times in open field. Nutritionally, the calyces have sufficient amounts of vitamins A, C, phosphorous, iron and calcium but tiny protein (FAO, 2004). The commercially important part of the plant is the fleshy calyx (sepals) surrounding the fruit (capsules). The whole plant can be used as beverage, or the dried calyces can be soaked in water to prepare a colorful cold drink, or may be boiled in water and taken as a hot drink. It also has some medicinal properties. The seeds contain 17.8–21% non-edible oil (Ahmed, (1980) and 20% protein, and are sometimes used for animal feed (Ahmed and Nour, (1981). The seeds are source of highly valued vegetable oil with properties similar to that of crude olive. In terms of their oil content, the seeds of Roselle are richer in lipids (22%) than most well-known seed oil such as those derived from Cotton (13%), Soybean (14%) and Palm fruit (20%) (Nzikou *et al.*, 2012).

Liquid form of Nitrogen, Phosphorus and potassium (NPK) is a fertilizer that is formulated to provide nitrogen, phosphorus and potassium in highly efficient way. Nitrogen promotes growth and development of plant and is essential for almost all crops. NPK, are the “Big 3” primary nutrients in commercial fertilizers required by plants in relatively higher quantity. Nitrogen is considered to be the most important nutrient, and plants absorb more nitrogen than any other element. Nitrogen is essential for healthy growth of plants. It is essential in the formation of protein, and protein makes up much of the tissues of most living things. Phosphorus, is linked to a plant’s ability to use and store energy, including the process of photosynthesis. It’s also needed to help plants grow and develop normally. Phosphorus in commercial fertilizers comes from phosphate rock. Potassium is the third major nutrient. It helps strengthening the plants’ abilities to resist disease and plays an important role in increasing crop yields and overall quality. It regulates the opening and closing of Stomata. Potassium also protects the plant when the weather is cold or dry, strengthening its root system and preventing wilt (Carvajal, *et al.,* 2018).

NPK are most essential nutrients required for the gowth and development of plants. The application of fertilizers is a major factor determining the crop productivity. Foliar fertilizer is being used widely as an alternative to soil nutrition supply or as a complementary practice (Jullien *et al.,* 2001; George, 2003; Akanbiat *et al.*,2009). Foliar spray is preferred over other methods of application due to the use of less amount of fertilizer, avoide soil problems, less ground water pollution in addition to the profound effect of plant growth, yield and yield related components (sabir e*t al* ., 2002; Hamayun *et al.,* 2011). Keeping in view the importance of NPK and the application of these macro-nutrients via foliar spray on Roselle for better nutrient use efficiency a project was design with the objective: To investigate the effect of foliar applied NPK on the vegetative and reproductive performance of Roselle.

Materials and methods

The experiment on "Influence of foliar applied nitrogen, phosphorous and potassium on the vegetative and reproductive attributes of roselle "*hibiscus sabdariffa*" was carried out at the Ornamental Horticulture Nursery, The University of Agriculture, Peshawar during the year 2020.

Experimental design and field preparation

The experiment was conducted in Randomized Complete Block Design (RCBD) based on single factor. The factor was NPK foliar application, having five concentrations. The plant to plant and row to row distance was kept 30 cm and 60 cm respectively.
The field was thoroughly ploughed and leveled. The seeds were planted 2.5 cm deep. Crop management practices such as Irrigation, weeding, hoeing and pest management etc were done equally to all treatments throughout experiment when needed. Seeds of Roselle (*Hibiscus sabdariffa* L.,) were obtained from Department of Horticulture, The University of Agriculture Peshawar Pakistan. The plants were relatively weak then normal growth.. Data were recorded on plant height, number of branches plant^{-1}, number of leaves plant^{-1}, stem diameter, leaf area plant^{-1}, days to first flowering, days to last flowering, number of calyces plant^{-1}, calyx diameter, calyces fresh weight plant^{-1}, pod size, number of seeds pod^{-1}.

Statistical Analysis

Data were subjected to analyses of variance. Software Statistix8.1 was used for computing analysis of variance and then least significant difference (LSD) test was used for significant findings.

Results and Discussion

Plant height (cm)

Data of plant height are given in Table 1. Tallest plants having height (104.75 cm) was observed in plots where plants were sprayed with NPK at 6g l^{-1} that was statistically similar to plant height (95.50 cm) recorded in plants that received NPK at 5 gl^{-1}. However, minimum plant height (78.00cm) was recorded in plants sprayed with distilled water (Control). It is clear from mean data that there was an increase in plant height with an increase in the concentration of foliar applied NPK up to 6 g l^{-1}. It might be due to the reason that NPK are primary essential nutrients required for the growth and development. Plants that received foliar applied NPK were healthy due to optimum growth and hence attained maximum height (Drostkar *et al*., 2016).

Number of branches plant^{-1}

Data of number of branches plant^{-1} are given in Table 1. Maximum number of branches plant^{-1} (13.500) was observed in plants that received foliar applied NPK at 6 gl^{-1} followed by no. of branches (11.75) observed in plants sprayed with NPK at 5gl^{-1}. However, the minimum number of branches plant^{-1} (4.00) was recorded in plants sprayed with distilled water (Control). Mean data pertaining to NPK showed that highest no. of branches (13.50) were recorded in plants sprayed with 6 gl^{-1} NPK. At the same concentration tallest plants were produced and hence those plants resulted in more number of leaves. Plants that received foliar applied NPK were healthy due to optimum growth and hence attained maximum number of branches (Kwon *et al. 2 019*).

Number of leaves plant^{-1}

Data pertaining to number of leaves plant^{-1} are given in Table 1. Maximum number of leaves plant^{-1} (301.25) was observed in plants sprayed with NPK at of 6 g l^{-1}. However minimum number of leaves plant^{-1} (58.50) was recorded in plants sprayed with distilled water (control). The major nutrients (NPK) are reported to enhance plant vegetative growth. Nitrogen, phosphorus and potassium have a significant effect on leaf and flower quality of Roselle plant (Singh *et al.*, 2004). NPK applications have direct impact on the number of leaves (Anamika and Lavania, 1990).

Stem diameter (mm)

Data of stem diameter are given in Table 1. Highest stem diameter (2.23 mm) plant^{-1} was measured in plots where plants were sprayed with NPK at 6 g l^{-1} followed by (1.40 mm) recorded in plots where NPK was sprayed at the rate of 5gl^{-1}, However minimum stem diameter plant^{-1} (0.77 mm) was recorded in plants sprayed distilled water (control). Plants that received optimum NPK produced more no. of leaves with good photosynthesis and resulted in an increase in stem diameter (Kwon, *et al.*, 2019).

Leaf area plant^{-1} (cm^2)

Data of leaf area are given in Table 1. Maximum leaf area plant^{-1} (119.75) was observed in plots where plants sprayed at 5g l^{-1} of NPK that was statistically similar to leaf area recorded in plants treated with 6g l^{-1} of NPK. However minimum leaf area (113.0) was recorded in plants sprayed with distilled water (control). Foliar application resulted in an increase in leaf area. NPK has significant role to augment cell division and cell expansion in plants (Marschner & Possingham, 1975; Mengel, 1977).

Days to First Flowering

Data of days to first flowering are given in Table 2. Mean data revealed that minimum days to first flowering (106.50) were noted in plants sprayed with NPK at 6g l^{-l}. However maximum days to first flowering (109.00) were recorded in plants sprayed with distilled water (control). The results showed that flowering was delayed with the application of NPK as compared to control plants. It might be due to the reason that NPK contain nitrogen that enhance the vegetative growth of the plant and that's why resulted in maximum days to first flower opening. The findings are in agreement with that of Qasim, et al. (2008) who reported a delay in flowering in response to the application of NPK.

Table1. Vegetative attributes of Roselle as affected by foliar applied NPK

NPK ($g\ L^{-1}$)	Plant height (cm)	No. of branches	No. of leaves	Stem diameter (mm)	Leaf area per plant (cm^2)
Control (Distilled water)	67.50 c	4.00 c	58.50 e	0.77 d	113.00 b
$3gl^{-1}$	78.00 bc	4.75 c	99.25 d	1.01 cd	113.25 b
$4g\ l^{-1}$	83.00 b	7.75 b	117.00 c	1.06 c	114.75 ab
$5g\ l^{-1}$	95.50 a	11.75 a	139.50 b	1.40 b	119.75 a
$6g\ l^{-1}$	104.75 a	13.50 a	301.25 a	2.23 a	118.25 ab
LSD ($P\leq 0.01$)	11.36	2.02	15.77	0.26	5.66

Means followed by different letters are significantly different from one another at 1% level of significance.

Days to Last Flowering

Data of days to last flowering are given in Table 2. Mean data revealed that maximum days to last flowering (128.00) were noted in plants sprayed with NPK at $6g\ l^{-1}$ followed by (118.75) recorded in foliar sprayed at the rate of $5g\ l^{-1}$, while the minimum days to last flowering (114.75) was recorded in plants sprayed with distilled water (control).The results showed that flowering was delayed in plants sprayed with NPK foliar application as compared to control plants. It is due to the reason that NPK contain nitrogen that enhanced the vegetative growth of plants and hence resulted in maximum days to last flower opening (Akbari, *et al.*, 2018).

Number of Calyces plant^{-1}

Data regarding number of calyces plant^{-1} are given in Table 2. Maximum number of calyces plant^{-1} (33.75) was observed in plants with foliar application of NPK at the rate of $6g\ l^{-1}$ followed by no. of calyces (23.50) observed in plants sprayed with NPK at the rate of $5\ gl^{-1}$. However minimum number of calyces plant^{-1} (9.75) was recorded in plants sprayed with distilled water (control). Calyx number was found higher with application of NPK because resulted in more plant height with a significant increase in leaf area and no. of branches and hence produced maximum no. of calyces as compared to the plants that were sprayed with distilled water (Babajide *et al.*, 2007; Abbas & Ali 2011).

Calyx Diameter

Data of calyx diameter are given in Table 2. Maximum calyx diameter (27.275 mm) plant^{-1} was recorded in plants that received foliar applied NPK at the rate of $6\ g\ L^{-1}$ followed by (26.64 mm) recorded in plants sprayed with NPK at the rate of $5g\ L^{-1}$, while the minimum calyx diameter plant^{-1} (23.835 mm) was recorded in plants sprayed with distilled water (control). NPK enhanced the plant height with better growth and development and resulted in a significant increase in the calyx diameter (Akanbi, 2002; Stefano et al., 2004)

Calyces Fresh Weight plant^{-1}

Data of calyces fresh weight plant^{-1} are given in Table 2. Maximum calyces fresh weight plant^{-1} (219.88 g) was recorded in plants sprayed with NPK at 6g L $^{-1}$ followed by (170.50 g) recorded in foliar application of NPK at 5g L^{-1}, however minimum calyces fresh weight plant^{-1} (89.94 g) was recorded in plants sprayed with distilled water(control). Egharevba and Law-Ogbomo reported that yield of Roselle was increased with the application of NPK. The plants yield is significantly increased with the application of NPK (Okosun et al., 2006).

Pod Size (mm)

Data of pod size are given in Table 2. Largest pod size (21.532 mm) was recorded in plants sprayed with NPK at 6 g L^{-1} followed by (20.808 mm) recorded in plants sprayed with NPK at the rate of 5g L^{-1}, while the minimum pod size (19.617 mm) was recorded in plants sprayed with distilled water(Control). NPK fertilization enhances flowering parameters, fruits size and seeds production of various medicinal and herbaceous plants (Abd-Elmalik, 1996)

Number of Seed Pod^{-1}.

Data of number of seed pod^{-1} are given in Table 2. Maximum number of seeds pod^{-1} (25.688) was recorded in plants sprayed with NPK at 6g l $^{-1}$ followed by (24.813) observed in plants sprayed with NPK at 5g l $^{-1}$, however least number of seeds plant^{-1} (21.688) was observed in plants sprayed with distilled water (Control). NPK cause to enhance root growth, flower initiation, seed and fruit development (Sharpley *et al.*, 1996).

Table 2. Mean values of reproductive attributes in Roselle as affected by foliar applied NPK

NPK(g L^{-1})	Days to First Flowering	Days to Last Flowering	Number of calyces plant^{-1}	Calyx Diameter	Calyces Fresh Weight plant^{-1}	Pod Size	Number of Seed Pod^{-1}
Control (Distilled water)	109.00 a	114.75 c	9.75 e	23.835 c	89.94 d	19.61 c	21.68 c
3gl^{-1}	108.00 b	115.75 bc	12.50 d	25.62 b	92.31cd	20.15 bc	24.06 b
4g l^{-1}	107.00 c	116.00 bc	15.50 c	25.63 b	96.50 c	20.53 b	24.50 b
5g l^{-1}	107.00 c	118.75 b	23.50 b	26.64 a	170.50 b	20.80 ab	24.81 ab
6g l^{-1}	106.50 c	128.00 a	33.75 a	27.27 a	219.88 a	21.53 a	25.68 a
LSD ($P \leq 0.01$)	0.88	3.98	1.7745	6.12	6.12	0.74	1.07

Means followed by different letters are significantly different from one another at 1% level of significance.

Conclusions

The application of NPK at the rate of 6 g L^{-1} resulted in taller plants, stem diameter, number of branches, number of leaves and leaf area minimum days to first flowering with maximum days to last flowering, number of calyces $plant^{-1}$, calyx diameter, calyces fresh weight $plant^{-1}$, pod size and number of seeds pod^{-1}. Minimum plant height, stem diameter, number of branches, number of leaves and leaf area, least days to first flowering with early days to last flowering, minimum number of calyces $plant^{-1}$,calyx diameter , calyces fresh weight $plant^{-1}$, pod size and number of seeds pod^{-1} were noted in plants sprayed with distilled water (Control plants). Foliar application of NPK at the rate of 6g L^{-1} is recommended for better vegetative and reproductive attributes of Roselle.

Declaration

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Data availability: From the author

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RESEARCH ARTICLE

Effect of mode of Zinc application on yield and yield components of Maize

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Abstract
There are three main methods of adding micronutrients to crops: soil fertilization, foliar spray and seed treatment. Each method has the potential to affect plant micronutrient nutrition. The objective of this research was to evaluate different methods of Zn application in maize. For this purpose, a field experiment was conducted at Agricultural Research Farm of NWFP Agricultural University Peshawar during summer 2006. The experiment was laid out in Randomized Complete Block design with three replications. Three methods of Zn application, soil application, foliar spray and seed treatment were included in the experiment. Three doses of Zinc sulphate (5, 10 and 15 kg ha^{-1}) were supplied to the maize crop as soil application before sowing. Solutions of 0% (water), 0.1%, 0.2% and 0.3% Zinc sulphate were sprayed on the crop at 5-6 leaf stage. For seed priming, the maize seed was soaked in 0% (water), 0.1%, 0.5% and 1% Zinc sulphate solutions for 16 h. The control treatment was dry seeds of maize. Soil application of Zinc sulphate at the rate of 15 kg ha^{-1} resulted in higher grains cob^{-1}, thousand grain weight and grain yield of maize. Planned mean comparison indicated that soil application of Zn was a superior fertilization method as compared to foliar or seed priming. It is concluded that soil application of Zinc sulphate at the rate of 15 kg ha^{-1} enhances yield and yield components of maize.

Keywords: Zinc suphate; maize crop; seed priming

Introduction

Zinc (Zn) deficiency in Pakistan was first recognized by Yoshida and Tanaka (1969) when Hadda disease of rice was diagnosed as Zn deficiency. Later research established the incidence of widespread Zn deficiency in all rice growing tracts of the country (Chaudhry and Sharif, 1975 and Kausar et al., 1976). Now Zn fertilization is widely recommended for rice. Zn deficiency has also been reported in wheat (Khattak and Parveen, 1986), maize (Rashid et al., 1979) and other crops (Tahir, 1981; Rashid and Qayyum, 1991). Based on extensive research on micronutrients in soils and crops, it has been estimated that now about 70% of the cultivated area of the country is considered Zn deficient. Zn deficiency is the third most serious crop nutrition problem in the country after N and P deficiency (Rashid, 1996). There are three main methods of applying micronutrients to crops: soil fertilization, foliar sprays and seed treatment. Foliar applications of micronutrient sprays are effective (Wilhelm *et al*., 1988; Savithri *et al*., 1999), but this method is too costly to be widely practiced by resource-poor farmers in some regions because of the amount of fertilizer, equipment and labour required for repeated spraying.

Likewise, the difficulty in obtaining high quality micronutrient fertilizers and spreading them evenly on the soil can be unaffordable. Treating seeds with micronutrients potentially provides a simple inexpensive method for improving micronutrient plant nutrition. Farmers in south Asia have responded favorably to seed priming, a simple technology of soaking seeds overnight in water prior to sowing (Harris, 1996; Harris *et al*., 1999). Seed priming in water has been shown to decrease time between sowing and emergence and to improve seedling vigour (Harris, 1996; Parera and Cantliffe, 1994). Likewise, priming seeds in solutions of macro or micronutrients has been shown to improve yield of rice (Peeran and Natanasabapathy, 1980), wheat (Khalid and Malik, 1982; Marcar and Graham, 1986; Wilhelm *et al*., 1988) and forage legumes (Sherrell, 1984), but the potential to damage the seed and inhibit germination by priming at high nutrient concentrations has also been reported (Roberts, 1948). There are several advantages of using seed priming to deliver micronutrients to seeds: the effects of uneven application of Zn to the soil are avoided as each seed is exposed to the nutrient; uptake is guaranteed; the amounts required are likely to be orders of magnitude less than for soil application. Conversely, risk of toxicity may be increased by priming.

There are several opinions regarding Zn application methods, for example, Graham and Rengel, (1993) reported that under Zn deficient soil conditions, plants grown from high Zn seeds produced more root and shoot biomass, enabling the plants to take up soil Zn more efficiently in later growth stages. Rush (1972) suggested that the application of low rates of Zn to rice seeds or dippling the roots of transplanted rice in a Zn solution may be effective alternative to broadcast applications of Zn fertilizer. Martens et al. (1973) concluded that band application of Zn fertilizer in contact with the corn seeds at rates ranging from 0.34 to 1.34 kg Zn ha^{-1} produced grains yields equal to those achieved when 26.9 kg Zn ha^{-1} as Zinc sulphate was broadcast on the soil surface and incorporated before planting. Yilmaz et al. (1997) also concluded that soil applied Zn was a superior fertilization method compared with Zn treated seed or foliar Zn applications. Kostas et al. (2005) reported that foliar spray of Zn did not lead to any significant increase in the yield components (spike mass, mass of kernels per spike and 1000 kernel mass) compared with the untreated plots. Other studies have not investigated a complete range of Zn seed treatment compare with standard soil or foliar Zn application methods (Slaton et al., 2001).

As very little work has been conducted on the comparison of different Zn application methods in maize, therefore the present experiment was designed to evaluate different methods of Zn application and to determine the most effective, viable and economical method of Zn application methods in maize for achieving higher yield and yield components of maize.

Materials and Methods

Experimental Site

The field experiment was conducted at Agricultural Research Farm of NWFP Agricultural University Peshawar during summer 2006. Peshawar has a warm to hot, semi-arid, sub-tropical, continental climate with mean annual rainfall of about 360 mm. Summer (May–September) has a mean maximum temperature of 40 ^oC and mean minimum temperature of 25 ^oC. Winter (December to the end of March) has mean minimum temperature of 4 ^oC and a maximum of 18.4 ^oC. The average winter rainfall is higher than that of summer. The highest winter rainfall has been recorded in March, while the highest summer rainfall is in August. The soil of experimental site was silty clay loams (fine, silty, mixed calcareous, hyperthermic Udic Haplustalf) deficient in N, P and available Zn, but have adequate K. Canal water is available for irrigation (Harris et al., 2007).

Experimental Procedure

The experiment was laid out in Randomized Complete Block design with three replications. Three methods of Zn application, soil application, foliar spray and seed treatment were included in the experiment. Zinc sulphate ($ZnSO_4.7H_2O$) was used as a source of Zn. Three doses of Zinc sulphate (5, 10 and 15 kg ha^{-1}) were supplied to the maize crop as soil application before sowing. Solutions of 0% (water), 0.1%, 0.2% and 0.3% Zinc sulphate were sprayed on the maize crop at 5-6 leaf stage. For seed priming, the maize seed was soaked in 0% (water), 0.1%, 0.5% and 1% Zinc sulphate solutions for 16 hours. The control treatment was dry seeds of maize. Nitrogen and phosphorus were applied at the rate of 120 and 100 kg ha^{-1}. Urea and single super phosphate were used as sources of N and P, respectively. All phosphorus was applied at the time of sowing while nitrogen was applied in three split doses i.e. 1/3 at the time of sowing, 1/3 with 2nd irrigation and 1/3 at pre-tassling stage. The field was thoroughly ploughed three times at proper moisture condition to make a fine seedbed for maize sowing. Seed of maize variety Azam was sown with the help of a hand hoe on June 20, 2006 in 3m by 3m plot at the rate of 60 kg ha^{-1}. The row to row distance was 70 cm while plant to plant distance of 20 cm was maintained by thinning. All other agronomic practices were carried out uniformly.
The data were recorded on number of emergence m^{-2}, cobs plant^{-1}, grains cob^{-1}, thousand grain weight and grain yield of maize. Emergence m^{-2} data were recorded by counting number of plants emerged in one meter row length at three randomly selected rows in each plot. The data were then converted to emergence m^{-2}. To record number of grains cob^{-1}, grains of five randomly selected plants in each plot were counted and then averaged. For thousand grain weight data, a random sample of thousand grains was taken from the grain yield of each plot and weighed with an electronic balance to record weight for thousand grains. For recording grain yield data, three central rows were harvested in each plot with the help of a sickle. Cobs were removed from the harvested plants, dried, shelled and weighed with the help of an electronic balance and then converted into kg ha^{-1}.

Statistical Analysis

The data were statistically analyzed using analysis of variance appropriate for randomized complete block design. Means were compared using LSD test at 0.05 level of probability, if the F-values were significant (Steel and Torrie, 1984).

Results and Discussion

Emergence m^{-2}

Data regarding emergence m^{-2} of maize are reported in Table 1. Analysis of the data indicated that Zn application methods did not significantly affect emergence m^{-2} of maize. However, seed primed with 1% Zinc sulphate showed higher emergence m^{-2} (10) followed by dry seed, water soaked seed and soil applied Zinc sulphate at the rate of 15 kg ha^{-1} all having same emergence m^{-2} (9). Minimum emergence m^{-2} (6) was recorded for soil applied Zn at the rate of 5 kg ha^{-1}. The foliar spray plots were considered as control because no foliar spray was done at the time of emergence of maize crop. Seed priming has been successfully demonstrated to improve germination and emergence in seeds of many crops, particularly seeds of vegetables and small seeded grasses (Heydecker and Coolbaer, 1977; Bradford, 1986). The results agree with the findings of Harris *et al*. (2001) who reported that the direct benefits of seed priming in all crops included faster emergence, better, more and uniform stands, less need to re-sow, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield.

Planned mean comparison indicated that the difference between control vs rest, control vs water and seed priming vs soil application were not significant.

Cobs palnt^{-1}

Data regarding cobs plant^{-1} of maize are reported in Table 1. Analysis of the data indicated that Zinc application methods did not significantly affect cobs plant^{-1} of maize.

Planned mean comparison indicated that the difference between control vs water was found significant while the differences among all other planned comparisons were not significant. Water soaked seed resulted in greater number of cob plant^{-1} as compared to control. The resulting improved stand establishment in primed seed plots may be a reason for more cobs plant^{-1} in water soaked seed plots. Similar results were noted by Sharma *et al*. (1993) who attributed higher yield to early floral initiation, more flowers and pods plant^{-1} in salicylic acid primed seed. The increase in cobs plant^{-1} of primed seed plots may be due to the fact that primed seed emerge faster and more uniformly and seedlings grow more vigorously, leading to a wide range of phonological and yield related benefits (Harris *et al*., 2000).

Grains cob^{-1}

Data regarding grains cob^{-1} of maize are reported in Table 1. Analysis of the data indicated that Zinc application methods significantly affected grains cob^{-1} of maize. Soil application of Zn at the rate of 15 kg ha^{-1} produced higher grains cob^{-1} (399) followed by foliar spray of water. Minimum grains cob^{-1} was recorded for foliar spray of 0.1% Zn solution.

Planned mean comparison indicated that the difference between foliar spray versus soil application was found significant while the differences among all other planned comparisons were not significant. Soil application of Zn produced significantly more grains cob^{-1} as compared to foliar spray. Similar results were reported by Gul and Enos (1988) who found that seed number per pod in lentil tended to increase with increase in phosphorus levels in combination with Zn.

Thousand grain weight

Data regarding thousand grain weight of maize are reported in Table 2. Analysis of the data indicated that Zinc application methods significantly affected thousand grain weight of maize. Soil application of Zn at the rate of 15 kg ha^{-1} resulted in higher grain weight followed by soil application of Zn at the rate of 10 kg ha^{-1}. Minimum thousand grain weight was recorded for control plots.

Planned mean comparison indicated that the differences among control versus rest, control versus water, seed priming versus foliar spray, seed priming versus soil application and foliar spray versus soil application of Zn were significant. Zn application and water soaking produced more grain weight as compared to control. Seed priming produced more grain weight than foliar spray and soil application of Zn produced more grain weight as compared to seed priming and foliar spray. Similar results were obtained by Gul and Enos (1988) who reported that Zn application alone produced heaviest grains in lentil. These results agree with Naveed et al. (2005) who reported that Zn application at the rate of 10 mg kg^{-1} resulted in 21% increase in grain weight of mungbean cultivars as compared to control.

Grain yield

Data regarding grain yield of maize are reported in Table 3. Analysis of the data indicated that Zn application methods significantly affected grain yield of maize. Soil application of Zn at the rate of 15 kg ha^{-1} produced higher grain yield followed by seed priming in 0.1% Zn solution. Minimum grain yield was recorded for foliar spray of 0.2% Zn solution.

Table 1. Mean square values for emergence m^{-2}, cobs $plant^{-1}$, grains cob^{-1}, thousand grain weight and grain yield of maize as affected by Zn application methods.

SOV	DF	Emergence m^{-2}	Cobs $plant^{-1}$	Grains cob^{-1}	Thousand grain weight (g)	Grain yield (kg ha^{-1})
Replications	2	9.35 ns	0.0063 ns	449.07 ns	0.527 ns	556132.65 ns
Treatments	11	6.65 ns	0.0040 ns	10272.05 *	721.54 *	716229.75 *
Control vs Rest	1	1.44 ns	0.0050 ns	640.18 ns	2303.09 *	204525.97 *
Control vs Water	1	1.04 ns	0.0150 *	1688.96 ns	216 *	489795.91 ns
SP vs FS	1		0.0070 ns	16226.0 ns	800 *	1551902.50 *
SP vs SA	1	7.73 ns	8.535 ns	3688.45 ns	3120.5 *	113378.68 ns
FS vs SA	1		0.0086 ns	35378 *	760.5 *	2504215.43 *
Error	22	4.8	0.0020	4196.52	9.77	306272.42

SP = seed priming, FS= foliar spray, SA = soil application

ns = Non significant, * = significant at 0.05 level of probability

Table 2. Emergence m^{-2}, cobs $plant^{-1}$, grains cob^{-1}, thousand grain weight and grain yield of maize as affected by Zn application methods.

Treatment	Emergence m^{-2}	Cobs $plant^{-1}$	Grains cob^{-1}	Thousand grain weight (g)	Grain yield (kg ha^{-1})
Dry seed (Control)	9	0.95	290	109	3619
Water soaking	9	1.05	256	121	3048
SP in 0.1% Zn solution	9	0.97	302	123	2857
SP in 0.5% Zn solution	8	1.00	309	126	3619
SP in 1% Zn solution	10	1.01	323	132	4000
FS of water	9	1.02	389	131	3619
FS of 0.1% Zn solution	7	1.00	297	134	3333
FS of 0.2% Zn solution	6	0.93	287	143	2190
FS of 0.3% Zn solution	6	0.94	170	145	2857
5 kg Zn ha^{-1}	6	0.98	320	140	3143
10 kg ha^{-1}	7	1.00	301	155	3714
15 kg ha^{-1}	9	1.02	399	166	4095
LSD	ns	Ns	61.07	2.95	521.77
Planned Mean comparisons					
Control	9 ns	0.95 ns	290 ns	109 *	3619 ns
Rest	8	0.99	305	138	3316
Control	9 ns	0.95 *	290 ns	109 *	3619 ns

Water	9	1.05	256	121	3048
Seed priming	9 *	1.00 ns	311 ns	127 *	3492 *
Foliar spray	6	0.96	251	141	2794
Seed priming	9 ns	1.00 ns	311 ns	127 *	3492 ns
Soil application	7	1.00	340	154	3651
Foliar spray	6 ns	0.96	251 *	141 *	2794 *
Soil application	7	1.00	340	154	3651

SP = seed priming, FS= foliar spray, SA = soil application
ns = Non significant, * = significant at 0.05 level of probability

Planned mean comparison indicated that the differences between seed priming versus foliar spray and foliar spray versus soil application of Zn were significant. Seed priming and soil application resulted in greater grain yield as compared to foliar spray. Similar results were reported by Yilmaz *et al*. (1997) who concluded that soil applied Zn was a superior fertilization method compared with Zn treated wheat seed or foliar Zn applications. Similar results were reported by Shah *et al*. (1985) and Rehman and Barnard (1988) who obtained maximum yields in maize and lentil with the application of 10 and 5.5 kg Zn ha^{-1} as compared to control, respectively. These results agree with Gill et al. (2002) who recorded significantly higher grain yield in maize with application of 15 kg Zn ha^{-1}. Likewise, Naveed et al. (2005) reported that Zn application at the rate of 10 mg kg^{-1} produced significantly higher grain yield in mungbean cultivars as compared to control. These results are also in line with Shukla and Mukhi, 1979; Sharma et al. (1990) who demonstrated increase in cob yield per plant with zinc supplementation by irrigation. However, these results do not agree with Johnson et al. (2005) who reported that soil fertilization with Zn had no effect on yield of chickpea, lentil, rice and wheat but resulted in small increase in concentration of Zn in wheat grain.

Declaration

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RESEARCH ARTICLE

Evaluation of oat accessions for different agronomic traits under agro-climatic conditions of narc Islamabad

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Abstract

Oat is one of the most commonly planted forages and a significant component of crop rotation in a farming system. Keeping in view the importance of oat crop, seven oat accessions were evaluated at National Agriculture Research Center, Islamabad during Rabi season 2020-21. Randomized complete block design with three replications with row to row distance 30 cm was maintained for sowing the aforementioned oat accessions. Significant variation was observed for all the studied traits except plant height and leaves tiller^{-1}. Highest mean values were observed for Jasper and Local Saryab for number of tillers plant^{-1} whereas Jasper was found to have maximum values for leaf area tiller^{-1} and leaf area index as well. Maximum flag leaf area was displayed by accession PP2-LV65 while the highest plant height was achieved by accession Local DIK. Maximum leaves tiller^{-1} was exhibited by S. 2000 while Local T.Jam achieved maximum green fodder yield and maximum dry matter yield t/ha. On the basis of high values for green fodder and dry matter yield Local T.Jam can be used for onward use for variety development.

Keywords: Oat; Germplasm; Agronomic traits; Fodder production and physiology

Introduction

Oat is one of the most often planted forages and a key component of crop rotation in a farming system, whether grown alone or in conjunction with the most prevalent annual legumes (Corleto, 1987). Its agronomic and nutritional qualities, as well as the growing popularity of organic agriculture, have reignited interest in this crop in recent few years. Furthermore, due to the fact that Oats are a good source of protein, carbohydrate, fiber, vitamins, minerals, and substances that are good for your health (e.g., polymers of fructose, and antioxidant molecules) (Peterson et al, 2005). Currently, the same oat cultivars used for fodder are also employed for grain production. Oat genotypes are typically chosen for high grain yield and harvest index, pest resistance, and/or resistance to environmental stress (Martinez et al., 2010). Fodder cultivars, on the other hand, must produce large volumes of highly digestible green fodder for animals, have strong regeneration ability after cutting, and be resistant to plant diseases that might limit fodder supply in producing regions (Stevens et al., 2004). The first

step in any breeding program is to determine the amount of variation that is present in the characters of agronomic importance within a large collection of materials in order to define the valuable populations to be considered further. Assessment of the genetic variability can be achieved using morphological measurements and phenotypic characterization (Greene et al., 2008). Bio-agronomic characterization using appropriate statistical methods is still a useful tool for the initial description and classification of oat collections, as it allows plant breeders to identify and select valuable genetic resources for direct use by farmers, breeding programs, or germplasm conservation and use planning (Achleitner et al., 2008).
The objectives of this study was to evaluate and explore and quantify the genetic variation of the main bio-agronomic traits and to define the oat genotypes for grain or fodder production that is applicable for breeding better accessions.

Materials and methods

The study titled "Evaluation of oat accessions for different agronomic traits under agro-climatic conditions of National Agriculture research council (NARC) Islamabad" was carried at national agriculture research center, Islamabad during Rabi season 2020-21. Twelve oat accessions (naming; No. 677, Australian, Local DIK, Local Sariab, Jasper, Local TandoJam, Local Lahore, No. 681, No. 708, Scott, PP2-LV65 and S. 2000) were laid out in RCB design (Randomized complete block) design with three replications. Seed rate of 40 kg per acre was kept and the field was irrigated according to the need of the crop. Other all-agronomic and cultural practices like, hoeing and weeding were carried out uniformly for all subplots.

Data measurement

Data on flag leaf area was calculated by measuring the length of flag leaf lamina from the base to the tip of lamina while flag width was measured from the middle portion of the lamina. Flag leaf area was, then, calculated using the following formula:
Flag leaf area = Flag leaf length × Flag leaf width × (Correction factor)
Plant height was measured in centimeters at maturity from ground level to the tip of panicle excluding awns using meter rod. Data on total tillers (productive and non-productive) were recorded by counted tillers from ten randomly selected plants in each entry and then average plant^{-1} was worked out. Total leaves were counted from ten randomly selected tillers in each plant and then average of leaves tiller^{-1} was worked out. Average leaf area tiller^{-1} was calculated by the following formula:

Leaf area tiller^{-1} = Tillers plant^{-1}×Leaves tiller^{-1}
Data on leaf area index was noted by using the following equation.

$$\text{Leaf area index} = \frac{\text{Total leaf area} \times \text{Tillers m}^{-2}}{10000}$$

Data on green fodder yield (t ha^{-1}) was determined after harvesting. The green fodder yield of selected plants was calculated by using balance and the average green fodder yield of the selected plants was computed in tons ha^{-1}. For data on dry matter yield (t ha^{-1}), a 27% dry matter yield was calculated from the calculated green fodder yield in tons ha^{-1}.

Statistical analysis

To get conclusive results of this experiment the field data was subjected to analysis of variance (ANOVA) procedure as recommended for alpha lattice design by Barreto *et al*. (1997). Least significant differences (LSD) test at 5% level of probability was used for means separation.

Results and Discussion

Flag leaf area (cm^2)

All the selected oat lines were observed significantly ($P<0.05$) different regarding flag leaf area (cm^2) (Table 1). Mean values of oat lines for flag leaf area (cm^2) ranged from 90.67 (cm^2) to 140.87 (cm^2). Among all accessions, PP2-LV65 gained maximum flag leaf area (cm^2) while No. 677 and Scott showed minimum flag leaf area (Table 2). Ak-Tahir (2014) tested oat genotypes and noticed significant variability for flag leaf area (cm^2).

Plant height(cm)

Mean values of oat lines for plant height ranged from 137.67 (cm) to 165.33 (cm). Among all accessions, Local DIK gained maximum plant height while No. 681 showed minimum plant height (Fig. 1). All the studied oat lines were observed non-significant ($P>0.05$) regarding plant height (Table 1). Al-Musa et al. (2021) studied oat genotypes and also found similar results for plant height

Tillersplant^{-1}

Results shows that all the selected oat lines were observed significantly ($P<0.05$) different regarding tillers plant^{-1}(Table 1). Mean values of oat lines for tillers per plant ranged from 4.33 to 7.66. Among all accessions, Local Saryab and Jasper gained maximum tillers plant^{-1}while No. 681displayed minimum tillers plant^{-1} (Table 2). Zaman et al. (2006) studied oat genotypes and noticed similar results for tillers per plant.

Table 1. Mean Square values of studied traits of oat lines sown at NARC Islamabad

Traits	Rep	Accessions	Error
Flag Leaf Area (cm^2)	15.84	1015.29	44.48
Tillers Plant^{-1}	0.04	41.39	15.33
Leaves per tiller^{-1}	0.02	0.42	0.40
Leaf Area Tillers^{-1}	1566.20	57531.80	12228.20
Leaf Area Index	0.35	12.94	2.75
Plant Height(cm)	181.03	151.36	266.64
Green Fodder yield (t ha^{-1})	100.31	202.15	93.65
Dry Matter yield (t ha^{-1})	7.31	14.74	6.82

Leaves tiller^{-1}

Statistical analysis was non-significant (P>0.05) regarding leaves tiller^{-1}(Table 1). Mean values of oat lines for leaves per tiller from 4.33 to 5.55. Among all accessions, S.2000 gained maximum leaves tiller^{-1}while PP2-LV65 showed minimum leaves tiller^{-1} (Table 2). Gurmani et al. (2021) tested oat genotypes and also found similar outcomes for leaves tiller^{-1}.

Leaf area tiller^{-1}

All the selected oat lines were observed significantly (P<0.05) different regarding leaf area tiller^{-1}(Table 1). Mean values of oat accessions for leaf area tiller^{-1} ranged from 478.73 (cm^2) to 936.63 (cm^2). Among all accessions, Jasper gained maximum leaf area tiller^{-1}while No. 708 showed minimum leaf area tiller^{-1} (Table 2). Bibi et al. (2021) evaluated oat germplasm and also noticed significant variability for leaf area tiller^{-1}.

Leaf Area Index

All the selected oat lines were observed significantly (P<0.05) different regarding leaf area index (Table 1). Mean values of oat lines for leaf area index ranged from 7.18 to 14.05. Among all accessions, Jasper gained maximum leaf area index while No. 708 showed minimum leaf area index (Table 2). Celik and Erten (2021) tested oat genotypes noticed significant variability for leaf area index.

Green fodder yield (t ha^{-1})

All the selected oat lines were observed significantly (P<0.05) different regarding green fodder yield t ha^{-1}(Table 1). Mean values of oat lines for green fodder yield ranged from 67.13 t/ha to 92.13 t/ha. Among all accessions, Local T. Jam gained maximum green fodder yield t ha^{-1}while PP2-LV65 showed minimum green fodder yield t ha^{-1} (Fig. 2). Jayashi et al. (2021) evaluated oat varieties and noticed significant variability for green fodder yield.

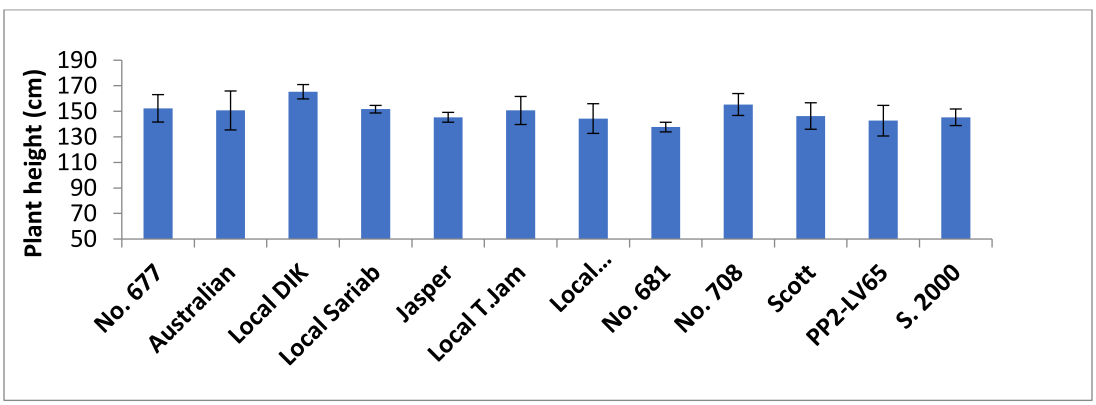

Figure I. Mean values and error bar graph for plant height

Dry Matter yield (t ha^{-1})

All the selected oat lines were observed significantly ($P<0.05$) different regarding dry matter yield t ha^{-1}(Table 1). Mean values of oat lines for dry matter yield ranged from 18.13 t/ha to 24.88 t/ha. Among all accessions, Local T. Jam gained maximum dry matter yield t ha^{-1}while PP2-LV65 showed minimum dry matter yield t ha^{-1} (fig. 3). Dangi (2021) studied oat genotypes and noticed similar results for dry matter yield.

Table 2. Flag leaf area, tilers plant-1, leaves per tillers, leaf area per tiller and leaf area index of different oat lines sown at NARC, Islamabad

Oat lines	Flag Leaf Area (cm^2)	Tillers Plant^{-1}	Leaves per tiller^{-1}	Leaf Area Tillers^{-1}	Leaf Area Index
No. 677	90.67	5.88	5.00	532.94	7.99
Australian	127.48	5.88	5.33	749.97	11.25
Local DIK	137.84	4.89	4.89	673.68	10.11
Local Sariab	107.83	7.66	5.00	826.14	12.39
Jasper	121.93	7.66	5.44	936.63	14.05
Local T.Jam	124.71	5.55	5.44	693.73	10.41
Local Lahore	102.71	4.88	4.61	499.65	7.49
No. 681	134.28	4.33	5.00	583.39	8.75
No. 708	93.59	5.11	5.22	478.73	7.18
Scott	90.67	7.33	5.44	663.46	9.95
PP2-LV65	140.87	5.66	4.33	798.33	11.97
S. 2000	120.63	5.44	5.55	652.48	9.79

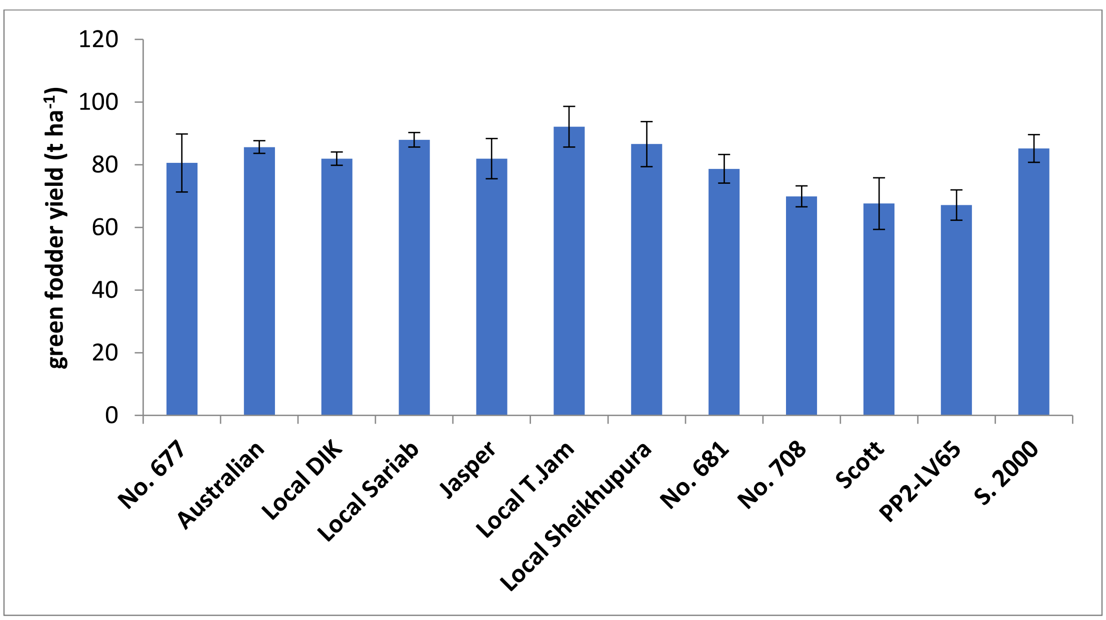

Figure 2. Mean values and error bar graph for green fodder yield t ha^{-1}

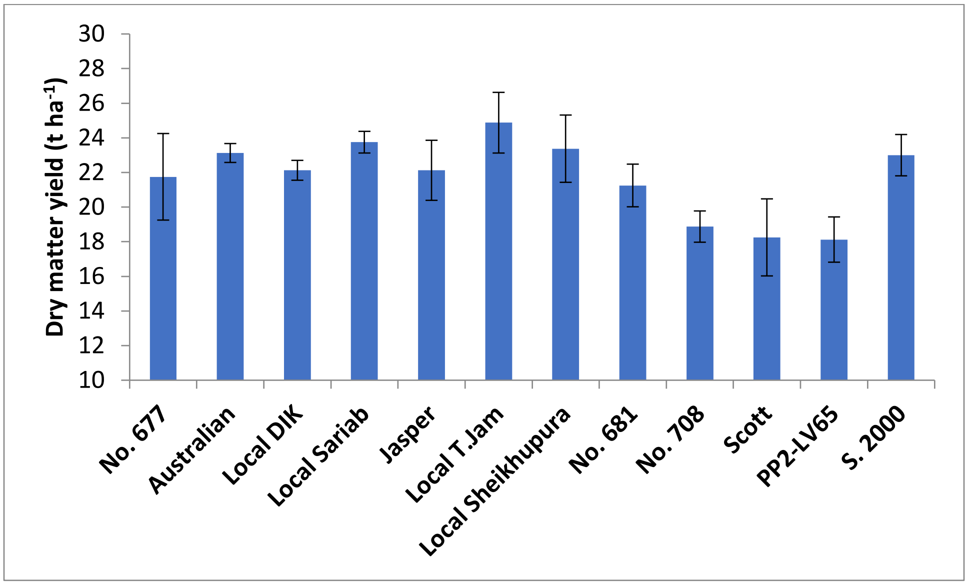

Figure 3. Mean values and error bar graph for dry matter yield t ha^{-1}

Conclusion

It was concluded that oat lines sown in NARC Islamabad significantly differed for studied traits excluding plant height and leaves tiller^{-1}. Oat genotype Jasper and Local Saryab produced higher number of tillers plant^{-1} while Jasper produced greater leaf area tiller^{-1} and leaf area index. The higher green fodder yield and dry matter yield t/ha was achieved by Local T. Jam and hence it could be selected for cultivation and may be include in the future oat breeding program.

Declaration

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RESEARCH ARTICLE

A Synergetic Approach of Agricultural Waste Management through vermicomposting

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Abstract

The present study was conducted to investigate the vermicomposting potential of epigeic earthworm, *Eisenia foetida* for rice straw and cow dung. The experiment comprised of ten treatments T_1 - [Chopped Rice straw + cow dung (1:1)] + 1kg worm), T_2 - [Unchopped Rice straw + cow dung (1:1)] + 1kg worm), T_3 - [Chopped Rice straw + cow dung (1:1)] + 2kg worm), T_4 - [Unchopped Rice straw + cow dung (1:1)]+ 2kg worm), T_5 - [Chopped Rice straw (70%) + soil (10%) + cow dung (20%) + 1kg worm], T_6 - [unchopped Rice straw (70%) + soil (10%) + cow dung (20%) + 1kg worm], T_7 - [Chopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2kg worm], T_8 - [Unchopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2kg worm], T_9 - [cow dung + 1kg worm] and T_{10} - [cow dung only], single replicate arranged in a randomized block design. The experimental results revealed that out of all the treatments, higher values of N, P and K were observed in T_7 - Chopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2 kg worm. The micronutrient content was also found higher in this treatment with higher biomass production. The multiplication of earthworms was significantly higher than only cow dung and other treatments. The vermicompost produced can be of significant value to the end users like farmers for replacement of chemical fertilizers and procuring better prices for the organic produce using such composting material locally available at much lower cost. Vermicomposting might prove to be a positive approach towards sustainable waste management system.

Keywords: Eisenia foetida; farmyard manure; vermicompost; soil; nutrient content

Introduction

Waste is produced as a result of every human activity. Significant amounts of solid waste are produced by industrial, residential and agricultural activities, which eventually cause an ecological imbalance (Lim and Wu, 2016). The primary agricultural waste products include cobs, husks, rice straw etc. Rice straw, which makes up nearly 45% of all rice produced globally, is the greatest agricultural crop leftover. India produces 112 MMT of rice straw annually and roughly 80% of this material is thrown away or left in fields as garbage (Singh et al., 2016). In India, it's typical to burn these leftovers in the fields. Burning rice straw results in a number of issues, including smog and air pollution, as well as the destruction of the rice straw's nutrients (Yan et al., 2013). A sustainable recycling waste management system is required to solve these issues.

The greatest approach towards agricultural waste management is through vermicomposting (Adhikary, 2012). It is a process of turning organic waste into high-quality organic manure made of worm cast by the action of earthworms (Chaudhuri et al., 2000). Vermicompost is currently a crucial component of an organic agricultural system since it is simple to manufacture, safe and has outstanding qualities. Vermicompost produced has great moisture-holding capacity, a low C/N ratio, high nutrients, aeration, structure and drainage (Ismail, 2005; Edwards et al., 2011). It is a nutrient-rich organic fertiliser rich in NPK, nitrogen-fixing and phosphate-solubilizing microorganisms (Christy, 2019). The total amount of nutrients in vermicompost is determined by the properties of the raw material utilized in the process. Cattle dung has a good C/N ratio and is palatable for earthworms, making it an ideal substrate for vermicomposting (Lim et al., 2016). Vermicompost improves the physical, chemical and biological characteristics of the soil and provides organic enrichment (Ansari and Jaikishun, 2011; Chauhan and Singh, 2013).

For environment friendly soil restoration techniques, agricultural wastes like rice straw and farmyard manure may be transformed into nutrient-rich vermicompost (Suthar, 2007). The best earthworm for vermicomposting is the epigeic species, *Eisenia foetida*. These earthworms are frequently used for vermicomposting because they are simple to handle, widely accessible and sensitive to environmental changes.

The goal of the current study was to assess *Eisenia foetida's* vermicomposting capacity for producing high-quality vermicompost from locally accessible organic waste sources (rice straw and farmyard manure). Vermicomposting research will help farmers produce eco-friendly biofertilizer, encourage sustainable agriculture and promote sound agricultural practices to preserve soil productivity. With these considerations in mind, the current study was created to explore the potential for vermicomposting using rice straw and cattle dung. Hence, studies were also designed to investigate the effectiveness of cattle dung and rice straw when combined in various ratios.

Material and Method

The research experiment was carried out in the vermicompost unit of school of organic farming, PAU, Ludhiana by arranging the vermi beds in randomized block design .The earthworm species used for the experiment was *Eisenia foetida*. The beds were arranged by keeping ten treatments replicated singly. The treatments were as follows T_1-[Chopped Rice straw + cow dung (1:1)]+ 1kg worm, T_2 -[Unchopped Rice straw + cow dung (1:1)]+ 1kg worm and T_3 -[Chopped Rice straw + cow dung (1:1)]+ 2kg worm, T_4 -[Unchopped Rice straw + cow dung (1:1)]+ 2kg worm, T_5 (Chopped Rice straw (70%) + soil (10%)+ cow dung (20%)] + 1 kg worm, T_6- [unchopped Rice straw (70%) + soil (10%) + cow dung (20%)] + 1 kg worm, T_7- [Chopped Rice straw (70%) + soil (10%) +cow dung (20%)] + 2 kg worm, T_8 – [Unchopped Rice straw (70%) + soil (10%) +cow dung (20%)] + 2 kg worm, T_9 - [cow dung + 1 kg worm] and T_{10} - [cow dung only].Before the start of experiment, raw material to be used for study is tested for TOC, TN, TP, TK, C:N ratio, Micronutrients (Zn, Cu, Mn and Fe) content. The above said material was composted in readymade vermibeds available in the market (6ft X 3ft X 1.5 ft). Optimum conditions like humidity, temperature were maintained throughout the experiment. To facilitate the process of composting, the organics in the beds were regularly stirred and mixed manually. During the study period every possible care was taken to avoid any contamination and to protect the earthworms from ants and natural enemies. Generally, the vermicompost was ready for use in 2 months, however different treatments has taken different days of preparation. After preparation of vermicompost, the samples were collected from nine spots from each bed. These nine spots were mixed together to make three representative samples. These representative samples were considered as replications. The total nutrient analysis was done using standard procedures. The data were analyzed statistically using SPSS software (standard version 23.0).

The parameters analyzed are as follows (A) Total Nitrogen Content (%) - The total nitrogen content was estimated by Micro-kjeldahl (Jackson, 1973) method. 0.25 g portions of the vermicompost was placed in the digestion tube and 1 g digestion mixture (400 parts of K_2SO_4, 20 parts of $CuSO_4$, 3 parts of HgO and 2 parts of SiO_2 powder) was added along with 4.5 ml of concentrated H_2SO_4 in each digestion tube. The sample was then digested on heater till a clear solution was obtained. After the digestion the sample was cooled and the volume was made upto 50 ml by adding distilled water. 5 ml aliquot was taken in the Kjeldahl flask containing 10 ml 40% NaOH. The solution was subjected to steam distillation. NH4-N evolved was absorbed in 4% boric acid mixed indicator solution until the appearance of green colour. The amount of nitrogen was determined by titration against N/70 H2SO4 until the appearance of green colour. (B) Total Phosphorus Content (%) - The total phosphorus content was estimated by using Vanado-molybdo-phosphoric yellow colour method in nitric acid (Jackson, 1967). 0.25 g test sample was digested in 10 ml diacid and volume was made upto 50 ml with distilled water. 2 ml of the filtrate prepared was mixed with 5 ml of vanadomolybate reagent in a volumetric flask . Intensity of yellow colour developed was measured on spectrophotometer at wavelength of 470 nm. (C) Total Potassium Content (%) - The total potassium content was estimated by Flame Photometer (Jackson, 1967) method. 2 ml of filtrate (diacid digested samples) was taken in 25 ml volumetric flask.The solution was fed to the atomizer assembly of the flame photometer, the galvanometer which had already been adjusted with standard K solutions. The reading was noted and the concentration of potassium was determined. (D) Total Organic Carbon (%) - total organic carbon was estimated using rapid titration (Walkley and Black, 1934) method. 0.1 g of test sample was weighed and 10 ml 1N potassium dichromate solution was added to it. After 30 minutes, 20 ml of sulphuric acid was added and then incubated further for 60 minutes. The solution was then diluted with 100 ml distilled water. Floculating agent sodium fluoride and 10 drops of diphenylamine indicator was added and titrated against N/2 FAS (Ferrous Ammonium Sulphate), until the colour shifted from turbid blue to brilliant green. Volume of N/2 FAS used was recorded for total organic carbon content determination. (E) Total manganese (Mn in ppm), total copper (Cu in ppm), total zinc (Zn in ppm) and total iron (Fe in %) was estimated by using the Atomic Absorption Spectrophotometer (AAS). The AAS works on the principle that an element whose quantity is to be estimated is irradiated with radiations from a cathode lamp, it absorbs the radiations in direct proportion to the concentration of the element. (F) To estimate the biomass production the earthworms were weighed (balance 2kg × 0.001 g) before starting the experiments and at the end of the experiment to determine the changes in body weight.

Statistical Analysis

The data obtained from the results were statistically analysed using SPSS software (standard version 23.0). The data of various parameters are expressed as the mean ± standard error of mean (SEM). The values were compared at 95% level of significance. A 'p' value of 0.05 was chosen as a standard for statically significant difference.

Results And Discussion

Initial Nutrient analysis of vermicompost from different test substrates

The nutrient content of test substrate used before the vermicomposting during the experimental period is shown in table 1. The nutrients i.e. nitrogen, phosphorus, potassium and total organic carbon varied among the organic agro wastes. Percent nitrogen content in FYM was 0.36 ± 0.03 % and in Rice straw was 0.39 ± 0.05 %. The phosphorus content recorded in FYM and rice straw was 0.36 ± 0.03% and 0.30 ± 0.04%, respectively. The percent potassium content was 0.54 ±0.05% in FYM and 0.77 ±0.07 % in rice straw. The total organic content was 47.32 ± 0.42% and 50.22 ± 0.52% in FYM and rice straw, respectively. The micronutrient concentration of Zn recorded was 88.12 ± 13.63 ppm in FYM and 62.23 ± 15.60 ppm in rice straw. The Cu concentration recorded was 12.43 ± 1.56 ppm in

FYM and 2.42 ± 0.96 ppm in rice straw. The Mn concentration recorded was 108.16 ± 15.24 ppm and 586.38 ± 23.45 ppm in FYM and rice straw respectively. The Fe concentration recorded was 0.20 ± 0.01% and 0.08 ± 0.03% in FYM and rice straw, respectively.

Table 1: Basic analysis of substrate used for vermicomposting

Manure property	Cow dung	Rice Straw
TOC (%)	47.32 ± 0.42	50.22 ± 0.52
TN (%)	0.36 ± 0.03	0.39 ± 0.05
TP (%)	0.36 ± 0.03	0.30 ± 0.04
TK (%)	0.54 ±0.05	0.77 ±0.07
C:N	51	45
Zn (ppm)	88.12 ± 13.63	62.23 ± 15.60
Cu(ppm)	12.43 ± 1.56	2.42 ± 0.96
Mn(ppm)	108.16 ± 15.24	586.38 ± 23.45
Fe (%)	0.20 ± 0.01	0.08 ± 0.03

Values are Mean ± S.E of triplicates

Final nutrient analysis of vermicompost from different test substrates

The total nitrogen content of the final vermicomposts is shown in table 2. Total nitrogen content increased in all the treatments. Among different test samples, increase in total nitrogen content was maximum in T7 and minimum in T10. The total nitrogen content followed the following decreasing order trend T7 (1.88 ± 0.05) > T5 (1.84 ± 0.04) > T8 (1.75 ± 0.03) > T3 (1.72 ± 0.03) > T6 (1.56 ± 0.02) > T4 (1.43 ± 0.02) > T1 (0.86 ± 0.05) > T2 (0.74 ± 0.03) > T9 (0.66 ± 0.02) > T10 (0.38 ± 0.02). There was significant difference noted between the all the treatments as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$). Earthworms helps in enhancing the nitrogen levels in the final vermicompost by adding body fluid, vermicast, mucus, enzymes and growth hormones Suthar (2007); Suthar (2009); (Bhat et al., 2018); Garg and Kaushik (2004) suggested that nitrogen content in the final vermicompost is related to the quality of the initial substrate used and due to mineralization of organic matter. Previous studies have reported that the nitrogen values ranges between (0.9 – 1. 5%). Earlier studies have reported the value of N between 0.9 and 1.5% (Waseem et al., 2013) but in (2009) Suthar reported that the value of nitrogen ranges between (2.49 – 3.17%) in the vermicompost. In 2012 Sujit Adhikary analysed the nitrogen content and reported it to be in the range of (0.51- 1.61%). According to (Sebayang et al., 2022) the percentage of nitrogen increased from 0.89% to 1.92 % following the process of vermicomposting.

Total organic carbon content of the final vermicomposts is shown in table 2. The total organic content decreased in all the test samples. Among different test samples, lowering of total organic content was maximum in T7 and minimum in T10. The total organic content followed the increasing trend as follows: T7 (17.23 ± 0.37) < T8 (18.46 ± 0.69) < T5 (20.42 ± 0.38) < T6 (22.63 ± 0.52) < T3 (23.45 ± 0.21) < T4 (24.12 ± 0.13) < T2 (26.86 ± 0.42) < T1 (28.02 ± 0.22) < T9 (29.02 ± 0.24) < T10 (30.94 ± 0.36). There was significant difference noted between the different treatments as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$). The carbon content in the final vermicompost is decreased due to microbial degradation and also, earthworms feed on the organic matter. The earthworms accelerate the decomposition process by feeding on the organic matter. Carbon is the major building block for all organisms present abundantly in the organic matter and hence, required for the composting process (Ansari and Jaikishun, 2011; Ansari and Rajpersaud, 2012). The present study results differ from the results of the previous study in which the organic carbon content ranges between (18.5–23%) Mane and Raskar (2012).

According to (Sebayang et al., 2022) the total carbon content decreases form 40.31% to 36.02% which coincide with the present study which shows similar decreasing trends.

C/N Ratio

The C:N ratio decreased during the vermicomposting process due to decomposition, microbial respiration, nitrogenous excretion (Solis-Mejia et al., 2012), mineralization and stabilization of organic matter (Kaushik and Garg, 2003). According to Senesi (1989) decrease in carbon:nitrogen to less than 20 reported show advanced degree of maturity in the organic matter waste. The C/N ratio in initial analysis of substrate was 45.29 which decreased to 19.07 after the process of vermicomposting (Sebayang et al., 2022).

The total phosphorus content of the final vermicomposts is shown in table 2. Among different test samples, increase in total phosphorus content was maximum in T7 and minimum in T10. The total phosphorus content followed the following decreasing order trend T7 (0.96 ± 0.05) > T8 (0.88 ± 0.03) > T5 (0.82 ± 0.03) > T6 (0.79 ± 0.05) > T3 (0.74 ± 0.02) > T4 (0.66 ± 0.02) >T1 (0.54 ± 0.02) > T9 (0.52 ± 0.02) > T2 (0.49 ± 0.03) > T10 (0.37 ± 0.03). There was significant difference noted between the all the treatments as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$). The present study results (0.3- 0.9%) are somewhat similar with the results obtained by Mane and Raskar (2012). The total phosphorus content recorded by Marlin and Rajeshkumar (2012) in the vermicompost obtained from city waste, saw dust, sugarcane trash, pressed mud and slaughter house waste was (2.68–3.61%) which is also different from the present study. The available phosphorus from the organic waste is released during the process of vermicomposting by the earthworm gut phosphatases and by P-solubilizing microorganisms present in the worm casts (Suthar, 2009; Goswami et al., 2013). The concentration of P recorded in initial substrate was 0.83% which increased to 1.15% after vermicosting (Sebayang et al., 2022). The present study results also concide with the findings of Kaplan, 2016).

Total Potassium content of the final vermicomposts is shown in the same table. Among different test samples increase in total potassium content was observed in all the treatments. The total potassium content followed the decreasing order trend T7 (1.78 ± 0.04) > T8 (1.69 ± 0.02) > T5 (1.53 ± 0.03) > T3 (1.41 ± 0.02) > T6 (1.26 ± 0.04) > T4 (1.21 ± 0.02) >T1 (0.78 ± 0.04) > T2 (0.69 ± 0.02) > T9 (0.67 ± 0.03) > T10 (0.55 ± 0.02). There was significant difference noted between the all the treatments as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$). The results obtained in the present study are somewhat similar with the previous studies by Nath et al. (2009). According to Nath et al. (2009) the total potassium content ranged between (0.64–0.76%) in the vermicompost obtained from rice straw and other waste material. The present study results are similar with the results reported by (Meenatchi, 2008 and Waseem et al., 2013) i.e the P content ranged between (0.54- 1.72%). Potassium, exchangeable calcium, phosphates etc. are present in the vermicompost in plant available form (Orozco et al., 1996). Due to microbial activity, vermicompost contains high level exchangeable K, which further increases the rate of mineralization (Suthar, 2007). The concentration of potassium ions in vermicompost The content of potassium increased from 1.25% to 2.17% following vermicomposting using *Eisenia foetida* (Sebayang et al., 2022) similar increasing trends are observed in the present study.

The total concentrations of the micronutrients, viz. zinc (T-Zn), copper (T-Cu), manganese (T-Mn) and iron (T-Fe) in different treatments vermicomposts are shown in table 4. Among different test substrates, the concentration of Zinc (ppm) followed the following decreasing trend T7 (973.68 ± 63.02) > T8 (907.23 ± 52.53) > T5 (842.50 ± 45.36) > T6 (779.75 ± 43.32) > T3 (564.24 ± 33.32) > T4 (512.35 ± 32.64) > T1 (424.62 ± 24.52) >T2 (314.82 ± 19.34) > T9 (153.57 ± 15.45) > T10 (102.38 ± 12.42). The concentration of Zinc showed significant difference in all the treatments as compared to T10 (Cow dung) according to Tukey's test ($p < 0.05$). The concentration of copper (ppm) followed the following decreasing trend T7 (49.60 ± 7.09) > T5 (45.26 ± 7.53) > T8 (39.81 ± 5.62) > T6

(37.28 ± 5.33) > T3 (36.19 ± 5.82) > T4 (32.78 ± 4.83) > T1 (27.82 ± 2.08) > T2 (27.23 ± 3.30) > T9 (19.82 ± 2.70) > T10 (11.45 ± 2.78). No significant difference was observed among the treatments but there was significant difference reported as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$).The high level of copper can be due to the presence of copper containing oxidizing enzymes. The concentration of manganese (ppm) followed the decreasing trend T7 (794.73 ± 63.35) > T8 (752.96 ± 57.99) > T5 (688.72 ± 52.56) > T6 (618.92 ± 45.41) > T3 (574.60 ± 35.92) > T4 (538.63 ± 39.43) > T1 (487.31 ± 23.59) > T2 (462.52 ± 42.19) > T9 (457.27 ± 37.24) > T10 (110.51 ± 17.38). There was significant difference recorded in the treatments as compared to T10 (Cow dung) according to Tukey's test ($p < 0.05$). The concentration of Iron (ppm) followed the following decreasing trend T7 (1.82 ± 0.04) > T5 (1.73 ± 0.05) > T8 (1.65 ± 0.05) > T6 (1.61 ± 0.05) > T3 (1.18 ± 0.06) > T4 (1.01 ± 0.03) > T1 (0.98 ± 0.04) > T2 (0.86 ± 0.05) > T9 (0.69 ± 0.02) > T10 (0.18 ± 0.02). Significant difference was recorded among the treatments according to Tukey's test ($p < 0.05$). The present study result varies from the earlier reported values 5.70–120.00 ppm for Zn, 2.00–37.70 ppm for Cu and 10.00–105.00 ppm for Mn (Meenatchi, 2008; Waseem et al., 2013). Vermicompost typically contains high concentrations of total NPK and micronutrients (Karmegam and Daniel, 2009; Prakash and Karmegam, 2010).The total content of Zinc, copper, manganese and iron is high in the vermicompost as compared to the substrate used. This indicates that these micro- elements accumulate in the vermicompost. The findings of the present study coincide with the results reported by early researchers (Ismail, 1997; Ansari and Sukhraj, 2010; Ansari et al., 2016). The plant nutrients such as N,P,K, Fe, Mn, Zn, Cu and other micronutrients present in the organic manures enhances their potential as alternative sources of nutrients to enhance the soil health and productivity (Subbaiah 2019).

Among all the treatments T7, T8, T5 and T6 are the best suited treatments to produce vermicompost with high NPK, high micronutrients and low C: N ratio.

Table 2: Final analysis of vermicompost produced

Treatment	TOC (%)	TN (%)	TP (%)	TK (%)	C:N
T_1	28.02 ± 0.22^{f}	0.86 ± 0.05^{c}	0.54 ± 0.02^{c}	0.78 ± 0.04^{c}	35.02
T_2	26.86 ± 0.42^{e}	0.74 ± 0.03^{b}	0.49 ± 0.03^{b}	0.69 ± 0.02^{b}	36.29
T_3	23.45 ± 0.21^{d}	1.72 ± 0.03^{f}	0.74 ± 0.02^{e}	1.41 ± 0.02^{e}	13.63
T_4	24.12 ± 0.13^{d}	1.43 ± 0.02^{d}	0.66 ± 0.02^{d}	1.21 ± 0.02^{d}	16.86
T_5	20.42 ± 0.38^{b}	1.84 ± 0.04^{g}	0.82 ± 0.03^{f}	1.53 ± 0.03^{f}	11.09
T_6	22.63 ± 0.52^{c}	1.56 ± 0.02^{e}	0.79 ± 0.05^{ef}	1.26 ± 0.04^{d}	14.50
T_7	17.23 ± 0.37^{a}	1.88 ± 0.05^{g}	0.96 ± 0.05^{h}	1.78 ± 0.04^{h}	9.16
T_8	18.46 ± 0.69^{a}	1.75 ± 0.03^{f}	0.88 ± 0.03^{g}	1.69 ± 0.02^{g}	10.54
T_9	29.02 ± 0.24^{f}	0.66 ± 0.02^{b}	0.52 ± 0.02^{bc}	0.67 ± 0.03^{b}	43.96
T_{10}	8.14 ± 0.36^{g}	0.38 ± 0.02^{a}	0.37 ± 0.03^{a}	0.55 ± 0.02^{d}	21.42

Values are Mean ± S.E of triplicates

Values with at least one same alphabetic superscript in column do not differ significantly ($p > 0.05$) w.r.t to treatments

Table 3: % Increase or decrease in TOC, TN, TP and TK among various treatments

Treatment	(%)Decrease in TOC		(%) increase in TN		(%) increase in TP		(%) increase in TK	
	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw
T_1	40.78	44.20	138.88	120.51	50.00	80.00	44.44	1.29
T_2	43.23	46.51	105.5	89.74	36.11	63.33	27.77	-10.38
T_3	50.44	53.30	377.77	341.02	105.55	146.66	161.11	83.11
T_4	49.02	51.97	297.22	266.66	83.33	120.00	124.07	57.14
T_5	56.84	59.33	411.11	371.79	127.77	173.33	183.33	98.70
T_6	52.17	54.93	333.33	300.00	119.44	163.33	133.33	63.63
T_7	63.58	65.69	422.22	382.05	166.66	220.00	229.62	131.16
T_8	60.98	63.24	386.11	348.71	144.44	193.33	212.96	119.48
T_9	38.67	42.21	83.33	69.23	108.64	73.33	24.07	-12.98
T_{10}	97.88	83.79	5.55	-2.56	2.77	23.33	9.25	-28.57

Table 4: Final analysis of micronutrients in the vermicompost

Treatment	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (%)
T_1	424.62 ± 24.52^{c}	27.82 ± 2.08^{bc}	487.31 ± 23.59^{b}	0.98 ± 0.04^{d}
T_2	314.82 ± 19.34^{b}	27.23 ± 3.30^{bc}	462.52 ± 42.19^{b}	0.86 ± 0.05^{c}
T_3	564.24 ± 33.32^{d}	36.19 ± 5.82^{cde}	574.60 ± 35.92^{bcd}	1.18 ± 0.06^{e}
T_4	512.35 ± 32.64^{cd}	32.78 ± 4.83^{bcd}	538.63 ± 39.43^{bc}	1.01 ± 0.03^{d}
T_5	842.50 ± 45.36^{ef}	45.26 ± 7.53^{de}	688.72 ± 52.56^{de}	1.73 ± 0.05^{fg}
T_6	779.75 ± 43.32^{e}	37.28 ± 5.33^{cde}	618.92 ± 45.41^{cd}	1.61 ± 0.05^{f}
T_7	973.68 ± 63.02^{g}	49.60 ± 7.09^{e}	794.73 ± 63.35^{e}	1.82 ± 0.04^{h}
T_8	907.23 ± 52.53^{fg}	39.81 ± 5.62^{cde}	752.96 ± 57.99^{e}	1.65 ± 0.05^{f}
T_9	153.57 ± 15.45^{a}	19.82 ± 2.70^{ab}	457.27 ± 37.24^{b}	0.69 ± 0.02^{b}
T_{10}	102.38 ± 12.42^{a}	11.45 ± 2.78^{a}	110.51 ± 17.38^{a}	0.18 ± 0.02^{a}

Values are Mean ± S.E of triplicates

Values with at least one same alphabetic superscript in column do not differ significantly ($p > 0.05$) w.r.t to treatments

Table 5: % Increase or decrease in micronutrients in the vermicompost

Treatment	(%) Increase in Zn		(%) increase in Cu		(%) increase in Mn		(%) increase in Fe	
	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw
T_1	381.86	582.33	123.81	1049.58	350.54	-16.89	390	1125
T_2	257.26	405.89	119.06	1025.20	327.62	-21.12	330	975
T_3	540.30	806.70	191.15	1395.45	431.25	-2.00	490	1375
T_4	481.42	723.31	163.71	1254.54	397.99	-8.14	405	1162.5
T_5	856.08	1253.84	264.11	1770.24	536.76	17.45	765	2062.5
T_6	784.87	1153.01	199.91	1440.49	472.35	5.54	705	1912.5
T_7	1004.94	1464.64	299.03	1949.58	634.77	35.53	810	2175
T_8	929.53	1357.86	220.27	1545.04	596.15	28.40	725	1962.5
T_9	74.27	146.77	59.45	719.00	322.77	-22.01	245	762.5
T_{10}	16.18	64.51	-7.88	373.14	2.17	-81.15	-10	125

Table 6: Earthworm population and biomass production during the study period

Treatment	Earthworm population (No.)	Biomass production(kg)	Days of preparation
Chopped Rice straw + cow dung (1:1)+ 1kg worm),	2221	324.67	60
Unchopped Rice straw + cow dung (1:1)+ 1kg worm)	2212	321.60	70
Chopped Rice straw + cow dung (1:1)+ 2kg worm)	2190	215.33	70
Unchopped Rice straw + cow dung (1:1) + 2kg worm	1145	195.75	75
Chopped Rice straw (70%) + soil (10%)+ cow dung (20%) + 1 kg worm	2961	428.40	90
Unchopped Rice straw (70%) + soil (10%) + cow dung (20%) + 1 kg worm	2349	310.21	138
Chopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2 kg worm	2384	350.78	118
Unchopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2 kg worm	2390	341.75	140
Cow dung (100%) + 1 kg worm	2372	264.00	65
Cow dung only	-	500.0	160
CD	14	NS	-

Correlation analysis among nutrients, Biomass production and Earthworm population

A correlation analysis among nutrients, biomass production and earthworm population is shown in table 5. The N content positively correlates with P and K (r= 0.961 and 0.974, respectively), Zn, Cu, Mn and Fe (r= 0.936, 0.949, 0.890 and 0.919, respectively) and negatively correlates with TOC and biomass (r= -0.042 and -0.234, respectively). Similarly P content positively correlates with K, Zn, Cu, Mn and Fe (r= 0.977, 0.970, 0.953, 0.937 and 0.959, respectively) and negatively correlates with TOC and biomass production (r= -0.070 and -0.155, respectively). The K content positively correlates with Zn, Cu, Mn and Fe (r= 0.950, 0.932, 0.885, and 0.905, respectively) and negatively correlates with TOC and biomass production (r= -0.176 and -0.127, respectively) indicating an increase in NPK content with decreasing TOC content. The content of Zn positively correlates with Cu, Mn and Fe (r= 0.957, 0.909 and 0.973, respectively) and content of Cu positively correlates with Mn and Fe (r=0.945 and 0.969, respectively) and negatively correlates with biomass production (r= -0.024 and -0.160, respectively). Similary, the content of Mn positively correlate with Fe (r=0.956) and negatively correlates with biomass production (r= -0.308). The results coincide with the findings of (Kováˇcik et al., 2022). No significant correlation was analyzed between the nutrients (N, P, K, Zn, Cu, Mn and Fe) and earthworm population.

Table 7: Correlation analysis among nutrients, Biomass production and Earthworm population

	N	P	K	TOC	Zn	Cu	Mn	Fe	Earthworm population	Biomass production
N	1	.961**	.974**	-0.042	.936**	.949**	.890**	.919**	0.182	-0.234
P		1	.977**	-0.070	.970**	.953**	.937**	.959**	0.293	-0.155
K			1	-0.176	.950**	.932**	.885**	.905**	0.205	-0.127
TOC				1	-0.122	0.048	0.239	0.067	0.261	-.719*
Zn					1	.957**	.909**	.973**	0.320	-0.024
Cu						1	.945**	.969**	0.317	-0.160
Mn							1	.956**	0.364	-0.308
Fe								1	0.457	-0.108
Earthworm population									1	.809**
Biomass production										1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

The efficacy of *Eisenia foetida* for bioconversion of agricultural waste like rice straw and farmyard manure (cowdung) into highly nutritive vermicompost is highly triumphant. The vermicompost produced was a homogenous mixture with dark color having high NPK value and low C:N ratio. Concentration of micronutrients like Cu, Zn and Mn were high in the vermicompost. The present study findings can be employed in improving the process of bio-management of agricultural waste by vermiconverting it into valuable, cost effective, pollution free and nutrient rich organic manure as well as it will assist the farmers to use eco-friendly biofertilizer and promoting good agricultural practices to maintain soil productivity and encouraging sustainable agriculture.

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