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REGULAR ARTICLE

Impact of potassium rates and their application time on dry matter partitioning, biomass and harvest index of maize (*Zea mays*) with and without cattle dung application

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ABSTRACT

Two field experiments were conducted to study the response of maize (*Zea mays* L., cv. Azam) to potassium (K) levels (30, 60, 90 kg ha^{-1}) and K application time (T_1 = full at sowing, T_2 = full at V9 stage (many ear shoots were easily visible upon dissection), and T_3 = 50% each at sowing and V9 stage with and without cattle dung. One experiment was carried out in the field where 5 t ha^{-1} cattle dung was applied (15 days before sowing), while the field under second experiment received no cattle dung (0 t ha^{-1}). The research was carried out at the Agronomy Research Farm of The University of Agriculture Peshawar during summer 2014. The experiments under both treatments were laid out in randomized complete block design using three replications. The results revealed that the K treated plots (rest) under both treatments had produced more number of leaves $plant^{-1}$ and mean leaf area, partitioned more dry matter into various plant parts (leaf, stem and ear), and produced more biomass yield and harvest index than control (K not applied). Cattle dung was found more beneficial in terms of more number of leaves $plant^{-1}$, higher mean leaf area, partitioning of more dry matter into leaf, stem and ear, and producing higher biomass yield and harvest index as compared to the treatment that received no cattle dung. Increasing the rate of K increased number of leaves $plant^{-1}$ and mean leaf area, partitioned more dry matter into various plant parts (leaf, stem and ear), produced more biomass yield and harvest index and vice versa (90 kg K ha^{-1} > 60 kg K ha^{-1} > 30 kg K ha^{-1}). Increase in number of leaves $plant^{-1}$, mean leaf area, dry matter partitioning into various plant parts (leaf, stem and ear), biomass yield and harvest index was observed when K was applied in two equal splits (50% each at sowing and V9 stage > 100% at sowing > 100% at V9 stage). It was concluded from this study that application of K at the highest rate of 90 kg ha^{-1} in two equal splits (50% at sowing + 50% at V9 stage) along with cattle dung (5 t ha^{-1}) could improve number and area of leaves, dry matter partitioning, biomass yield and harvest index under limited irrigation condition.

Keywords: Cattle manure; Potassium; Maize; Leaf area; Dry matter portioning; Growth stages; Biomass yield; Harvest index

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in Pakistan after wheat and rice. In Northwest Pakistan (Khyber Pakhtunkhwa) it ranked 2nd after wheat in its importance. During 2012, maize was cultivated on an area of 1087.3 thousand hectares with the total production of 4338.3 thousand tons and national average yield of 3990 kg ha^{-1}, while in Northwest Pakistan (Khyber Pakhtunkhwa) it is grown on about 475.3 thousand hectares with a total production of 887.8 thousand tones and very low average yield of 1868 kg ha^{-1} (MINFAL, 2012). In Northwest Pakistan, the main reason for low yield of maize is attributed to the imbalanced use of chemical fertilizers (Amanullah et al., 2010a, 2012, 2014). The farmers in this region apply potassium (K) only to tobacco crop because of industry regulations, and the two major crops (wheat and maize) do not received any K. Potassium deficiency has been reported in many soils of Pakistan due to intensive cropping system (Malik et al., 1989; Ahmad and Rashid, 2003; Akhtar et al., 2003) because significant quantity of K is removed by crops (Singh and Jones, 1975; Mengel et al., 2001; White, 2003). Under K deficient soils, photosynthesis is significantly reduced (Hermans et al., 2006) which is responsible for low yield in maize (Asif et al., 2007; Amanullah et al., 2007), brassica (Amanullah et al., 2011)

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and sunflower (Amanullah and Khan, 2010). Potassium is known to play a significant role in the activation of more than 60 enzymes which catalyze various metabolic processes (Evans and Wildes, 1971), and helps in uptake and translocation of nitrates from root to aerial parts of plants (Das et al., 1976).

Proper application and management of organic manures and chemical fertilizers contribute about 50 to 60% increases in field crops productivity (DIPA, 2006). Several organic materials such as cattle dung, poultry dropping, pig dung and refuse compost have been recommended to increase crop yield in different parts of the world (Reijnties et al., 1992; Sobulo and Babalola, 1992; Olayinka, 1996; Olayinka et al., 1998; Ismail et al., 1999; Adepetu et al., 2005; Ayoola and Makinde, 2008; Hidayatullah et al., 2013). Nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma et al., 1991; Hidayatullah et al., 2013). Cattle dung is an important resource for crop production and restores essential nutrients depleted due to intensive cropping practices (Sharpley and Smith, 1995; Bahman and James, 1999; Materechera, 2010). There is lack of research to investigate impact of combine application of potassium and cattle dung on maize growth and yield. This research project was therefore designed with an objective to find out suitable K level and its application time with and without cattle manures to increase maize productivity under potassium deficient soils.

MATERIALS AND METHODS

Field experiments were conducted to investigate the effects of potassium levels (30, 60, 90 kg ha^{-1}) and its application time (full (100%) at sowing, full (100%) at V9 stage: Many ear shoots were easily visible upon dissection (Amanullah et al., 2010b), and 50% each at sowing and V9 stage) on growth and yield of maize (cv. Azam) with (5 t ha^{-1}) and without (0 t ha^{-1}) cattle dung (CD). The well decomposed and dry CD (5 t ha^{-1}) was applied to the field 15 days before sowing of maize crop. The research was carried out at the Agronomy Research Farm of The University of Agriculture Peshawar, during summer 2014. The experimental farm is located at 34.01° N latitude, 71.35° E longitude, at an altitude of 350 m above sea level in Peshawar valley. Peshawar (34.0167° N and 71.5833° E) is located about 1600 km North of the Indian Ocean and has continental type of climate. The research farm is irrigated by Warsak canal from river Kabul. Soil is clay loam, low in organic matter (0.87 %), phosphorus (6.57 mg kg^{-1}), potassium (121 mg kg^{-1}) and alkaline (pH 8.2) and is calcareous in nature (Amanullah et al., 2009). The experiment was performed in randomized complete block design having three replications. A plot size of 3 m x 3.5 m was used. Each plot consisted of five rows, 3 m long and 70 cm apart. A uniform dose of 120 kg N ha^{-1} as urea in two equal splits i.e. half at sowing, and half at V9 stage was applied. Phosphorus was applied at the rate of 60 kg P_2O_5 ha^{-1} as single super phosphate at seedbed preparation. All other agronomic practices were kept uniform and normal for all the treatments. Data were recorded on growth parameters (number of leaves plant^{-1} and mean leaf area), dry matter partitioning at silking and physiological maturity (stem, leaf and ear), biomass yield and harvest index. Data on number of leaves plant^{-1} was recorded by counting the total number of leaves on five randomly selected plants and average was calculated. Leaf area index was calculated as leaf area per plant divided by ground area per plant. For data on dry matter partitioning at silking and physiological maturity, five plants at each stage were harvested. The leaves, stem and ears were separated. The materials were sun dried up to constant weight. The materials were weighed by electronic balance and then dry weight of leaf, stem, and ears per plant was determined. Data on biomass yield was recorded by harvesting three central rows in each plot, the material was sun dried for several days and weighed, and then converted into biomass yield (kg ha^{-1}). The dry material harvest for biomass yield was threshed; the grains were separated, cleaned, weighed and converted into grain yield (kg ha^{-1}). The harvest index for each treatment was calculated by using the following formula:

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biomass yield}} \times 100$$

Statistical analysis

Data was statistically analyzed according to Steel et al. (1996) and means was composed using LSD test ($P < 0.05$).

RESULTS

Plant growth

Number of leaves plant^{-1} and mean leaf area was significantly affected by control vs. rest, cattle dung, K levels and K application timing, while all interactions were found non-significant (Table 1). The treated plots (rest) had significantly maximum number of eaves plant^{-1} and mean single leaf area than control (Table 2). Maximum number of leaves plant^{-1} and mean single leaf area was recorded from the field applied cattle dung as compared to the field without cattle dung. Among the three K levels, the maximum number of leaves plant^{-1} and mean single leaf area was recorded for the plots treated with the highest K level (90 > 60 > 30 kg ha^{-1}). Among the three K application timings, maximum number of leaves plant^{-} and mean single leaf area was recorded for the plots which

Table 1: Analysis of variance for number of leaves plant^{-1}, mean leaf area (cm^2), dry matter partitioning into stem, leaf, ear and total (g plant^{-1}) at silking of maize (*Zea mays* L.) as affected by potassium (K) levels (kg ha^{-1}) and its application time with and without cattle dung (CD)

Source of variance	Degree of freedom	Leaves plant^{-1}	Mea leaf area (cm^2)	Stem dry matter (g plant^{-1})	Leaf dry matter (g plant^{-1})	Ear dry matter (g plant^{-1})	Total dry matter (g plant^{-1})
Cattle dung (CD)	1	*†	***	*	*	**	***
Rep (CD)	4	ns	ns	ns	ns	ns	ns
Treatment (Tr)	9	***	***	***	***	***	***
Control vs rest	1	**	***	***	***	***	***
Application timing (T)	2	*	*	*	**	*	***
K Levels (K)	2	***	**	***	***	***	***
T × KL	4	ns	ns	ns	ns	ns	ns
CD × Tr	9	ns	ns	ns	ns	ns	ns
CD × control vs rest	1	ns	ns	ns	ns	ns	ns
CD × T	2	ns	ns	ns	ns	ns	ns
CD × K	2	ns	ns	ns	ns	ns	ns
CD × T × K	4	ns	ns	ns	ns	ns	ns
Error	36	–	–	–	–	–	–
Total	59	–	–	–	–	–	–
CV–I (%)	7.25	3.81	15.83	7.67	1.87	2.97	–
CV–II (%)	4.52	4.76	11.61	5.36	4.54	4.68	–

†,*,**,***Indicates that data is significant at 5, 1 and 0.1% level of probability, respectively. The word ns stand for the non–significant data at 5% level of probability. ( ) stands for splits of 9 degrees of freedom

Table 2: Number of leaves plant^{-1}, mean leaf area (cm^2), dry matter partitioning into stem, leaf, ear and total (g plant^{-1}) at silking of maize (*Zea mays* L.) as affected by potassium (K) levels (kg ha^{-1}) and its application time with and without cattle dung (CD)

Treatments	Leaves plant^{-1}	Mean leaf area (cm^2)	Stem dry matter (g plant^{-1})	Leaf dry matter (g plant^{-1})	Ear dry matter (g plant^{-1})	Total dry matter (g plant^{-1})
30 kg K ha^{-1}	11b†	351.2b	38.6c	31.8c	56.6c	127.0c
60 kg K ha^{-1}	11b	367.1a	46.5b	33.4b	60.4b	140.4b
90 kg K ha^{-1}	12a	373.6a	50.3a	35.3a	64.9a	150.6a
100% K at sowing	12a	364.1ab	46.1a	33.1b	61.3a	140.5a
100% K at V9 stage	11b	354.9b	42.5b	32.6b	59.0b	134.1b
50% K each at sowing and V9 stage	12a	372.9a	47.0a	34.7a	61.7a	143.4a
With cattle dung	12a	382.3a	48.1a	34.5a	62.0a	144.6a
Without cattle dung	11b	345.7b	42.2b	32.5b	59.3b	134.1b
Control plots	11b	337b	31.9b	28.0b	53.5b	113.5b
Treated (rest) plots	12a	364a	45.2a	33.5a	60.6a	139.3a

†means of the same category followed by different letters are significantly different from each other using LSD test ($P \leq 0.05$)

received K in two equal splits (50% split at sowing and V9 stage >100 % at sowing >100 % at V9 stage).

Dry matter partitioning

Statistical analysis of data revealed that dry matter partitioning into stem, leaf, ear and total dry matter accumulation per plant at silking was significantly affected by control vs. rest, cattle dung, K levels and K application timing, while all interaction were found non-significant (Table 1). At silking, the treated plots had significantly higher stem, leaf, ear and total dry matter (g plant^{-1}) than control (Table 2). The highest stem, leaf, ear and total dry matter (g plant^{-1}) was recorded from the field under cattle dung (5 t ha^{-1}) as compared to the field without cattle dung (0 t ha^{-1}) at silking of maize. Among the K levels, the highest stem, leaf, ear and total dry matter (g plant^{-1}) was recorded for the plots treated with the highest K level (90 > 60 > 30 kg ha^{-1}) at silking. Among the three K application timings, maximum stem, leaf, ear and total dry matter per plant (g) was recorded for the plots which received K in two equal splits (50% split at sowing and V9 stage > 100 % at sowing > 100 % at V9 stage) at silking (Table 2).

The ANOVA table (Table 3) indicated that dry matter partitioning into stem, leaf, ear and total dry matter accumulation per plant at physiological maturity was significantly affected by control vs. rest, cattle dung, K levels and K application timing, while all interaction were found non-significant. The treated plots also had significantly higher stem, leaf, ear and total dry matter (g plant^{-1}) than control at physiological maturity (Table 4). The highest stem, leaf, ear and total dry matter (g plant^{-1}) at physiological maturity was recorded from the field under

Table 3: Analysis of variance for dry matter partitioning into stem, leaf, ear and total (g plant^{-1}) at physiological maturity, biomass yield (kg ha^{-1}) and harvest index (%) of maize (*Zea mays* L.) as affected by potassium (K) levels (kg ha^{-1}) and its application time with and without cattle dung (CD)

Source of variance	Degree of freedom	Stem dry matter (g plant^{-1})	Leaf dry matter (g plant^{-1})	Ear dry matter (g plant^{-1})	Total dry matter (g plant^{-1})	Biomass yield (kg ha^{-1})	Harvest index (%)
Cattle dung (CD)	1	***†	*	***	***	**	ns
Replications (CD)	4	ns	ns	ns	ns	ns	ns
Treatment (Tr)	9	***	***	***	***	***	ns
Control vs rest	1	***	***	***	***	***	ns
Application timing (T)	2	***	***	***	***	*	ns
K Levels (K)	2	***	***	***	***	***	*
T × KL	4	ns	**	ns	ns	ns	ns
CD × Tr	9	*	ns	**	**	ns	ns
CD × control vs rest	1	ns	ns	***	**	ns	ns
CD × T	2	*	ns	ns	ns	ns	ns
CD × K	2	ns	ns	***	**	ns	ns
CD × T × K	4	ns	ns	ns	ns	ns	ns
Error	36	–	–	–	–	–	–
Total	59	–	–	–	–	–	–
CV–I (%)	3.71	3.97	3.80	2.21	3.79	5.01	–
CV–II (%)	3.04	2.59	3.73	2.33	3.41	5.72	–

†,*,**,*** indicates that data is significant at 5, 1 and 0.1% level of probability, respectively. The word ns stand for the non–significant data at 5% level of probability. ( ) stands for splits of 9 degrees of freedom

Table 4: Dry matter partitioning into stem, leaf, ear and total (g plant^{-1}) at physiological maturity, biomass yield (kg ha^{-1}) and harvest index (%) of maize (*Zea mays* L.) as affected by potassium (K) levels (kg ha^{-1}) and its application time with and without cattle dung (CD)

Treatments	Stem dry matter (g plant^{-1})	Leaf dry matter (g plant^{-1})	Ear dry matter (g plant^{-1})	Total dry matter (g plant^{-1})	Biomass yield (kg ha^{-1})	Harvest index (%)
30 kg K ha^{-1}	71.9c†	20.0c	122.6c	214.4c	10687c	36.9b
60 kg K ha^{-1}	74.6b	23.8b	131.2b	229.6b	11457b	38.1ab
90 kg K ha^{-1}	85.0a	27.2a	137.9a	250.1a	11766a	39.2a
100% K at sowing	77.9b	23.6b	130.0b	231.6a	11265ab	38.5a
100% K at V9 stage	73.3c	22.4c	126.9b	222.5c	11142b	37.4a
50% K each at sowing and V9 stage	80.3a	25.0a	134.8a	240.0a	11503a	38.3a
With cattle dung	81.0a	24.1a	140.2a	245.4a	11728a	38.4
Without cattle dung	73.4b	23.2b	120.9b	217.4b	10879b	37.7
Control plots	40.3b	18.5b	110.3b	169.1b	9936b	37.4b
Treated (rest) plots	77.2a	23.7a	130.6a	231.4a	11304a	38.1a

†means of the same category followed by different letters are significantly different from each other using LSD test (P ≤ 0.05)

cattle dung (5 t ha^{-1}) as compared to the field without cattle dung (0 t ha^{-1}). Among the K levels, the highest stem, leaf, ear and total dry matter (g plant^{-1}) was recorded for the plots treated with the highest K level (90 > 60 > 30 kg ha^{-1}) as shown in Table 4. Among the three K application timings (Table 4), maximum stem, leaf, ear and total dry matter per plant (g) was recorded for the plots which received K in two equal splits (50% split at sowing and V9 stage > 100% at sowing > 100% at V9 stage).

Biomass yield and harvest index

Biomass yield of maize was significantly affected by control vs. rest, cattle dung, K levels and K application timing, while all interaction were found non-significant (Table 3). The treated plots (rest) had significantly higher biomass yield (11304 kg ha^{-1}) than control (9936 kg ha^{-1}) (Table 4). The highest biomass yield (11728 kg ha^{-1}) was obtained from the field applied with cattle dung as compared to field without cattle dung (10879 kg ha^{-1}). Among the K levels, the highest biomass yield (11766 kg ha^{-1}) was recorded for the plots treated with the highest K level (90 kg ha^{-1}), followed by (11457 kg ha^{-1}) with 60 kg K ha^{-1}, while the lowest biomass yield (10687 kg ha^{-1}) was obtained from the plots that received 30 kg K ha^{-1} (90 > 60 > 30 kg K ha^{-1}). the K application timing, the highest biomass yield (11503 kg ha^{-1}) was recorded for the plots which received K in two equal splits (50% K_2O at sowing time + 50% K_2O at V9 stage), followed by in the plots which received 100% K_2O at sowing time (11265 kg ha^{-1}) which was at par with 100% K_2O applied at V9 stage (Table 4). The analysis of data revealed that harvest index (%) of maize was significantly affected by control vs. rest, K levels, while cattle dung, K application timing and all interaction were found non-significant (Table 3). The treated plots (rest) had higher harvest index (38.1%) than control with 37.4% (Table 4). Among the K levels, the highest harvest index (39.2%) was recorded for the plots treated with the highest K level (90 kg ha^{-1}), followed by 38.1% with 60 kg K ha^{-1}, while the lowest harvest index (36.9%) was obtained from the plots that received 30 kg K ha^{-1}. Though the effect of cattle dung was non-significant, however, harvest index was higher (38.4%) for the field under cattle dung than without cattle dung (37.7%).

DISCUSSION

Application of potassium (K) at the highest rate (90 kg ha^{-1}) improved growth variables such as number of leaves plant^{-1} and mean leaf area of maize. According to Akhtar et al. (2003) and Asif et al. (2007), the main reason for improved mean leaf area at higher K level could be attributed to the activation of several enzymes, increase in protein synthesis, N uptake and utilization that resulted in the normal growth of maize and hence leaf number and area was increased. Number of leaves plant^{-1} and mean leaf area of maize was significantly increased when K was applied in two equal splits (50% each at sowing and V9 stage). Due to split application of K, the maize plants probably may have absorbed more K with the passage of time during their growth period (Saleem et al., 2011) and hence both leaf number and area was increased. The single application of K at early (sowing) or late (V9 stage) growth stages on the other hand caused the plants to be under K stress and did not provided sufficient amount of K to be available for the plants at different growth stages probably may have decreased photosynthesis (Hermans et al., 2006) and enzymes activation (Evans and Wildes, 1971) therefore reduced both leaf number and area. In contrast to our results, other scientists (Chaudary and Malik, 2000) found no significant differences in maize growth parameters under different K levels. The experiment under cattle dung performed better in terms of higher number of leaves plant^{-1} and mean leaf area in maize. According to Rahman et al. (2008), application of cattle slurry did not showed a significant effect on number of leaves but the average leaf area plant^{-1} was increased significantly. The increase in number of leaves plant^{-1} and leaf area plant^{-1} with organic fertilizer application was reported earlier Goenadi (1985). Mhlontlo et al. (2007) found significant increase in number of leaves with an increase in sheep manure application rate. Cow dung manure greatly improve water holding capacity, soil aeration, soil structure, nutrient retention and microbial activity in the soil (Anon, 2007; Fageria, 2009) and the increase availability of nutrients from cow manure in the soil improve growth and development in crops (Anon, 2007). Mahadi et al. (2012) reported that leaf area index increases with application of cow dung.

Increasing K level up to 90 kg ha^{-1}, application of K in two equal splits, and application of dung increased partitioning of dry matter into various plant parts of maize. The probable reason for improvement in dry matter partitioning at higher levels of K, split application of K and cattle dung was due to the prolonged vegetative growth and higher crop growth rates (data not shown). The increase in number of leaves and area of maize showed positive relationship with increase in dry matter partioning and total dry matter accumulation. According to Baque et al. (2006), dry matter partitioning increases with K application. Amanullah et al. (2007) reported that stover yield in maize increased with application of K splits. Detpiratmongkol et al. (2014) compared different organic manures and reported that the maximum stem dry weight of 11.06 g plant^{-1} was obtained in plots under chicken manure whereas the cow dung gave the lowest stem dry weight (6.37 g plant^{-1}). The trend of increasing leaf dry weight with the application of organic manure was earlier reported by Goenadi (1985). Application of organic manure probably may have increased the availability of nutrients and water holding capacity of the soil resulted in enhanced growth and yield (Manhas and Gill, 2010; Abdelrazzag, 2002; Rashid et al., 2013; Hidyatullah et al., 2013). According to several researchers (Mhlontlo et al., 2007; Sanjutra et al., 2008; Ramesh et al., 2011; Mishra and Jain, 2013) reported increase in dry matter with application of sheep manure.

Biomass yield increased with K application at the highest rate of 90 kg ha^{-1}, K applied in two equal splits, and application of cattle dung. The probable reason for increase in biomass yield of maize with K application probably might be due to the increased rate of CO_2 assimilation, stabilized the stomata regulation, improved stomata closure and enzyme activity as a result of which more carbohydrates might have produced and hence increased biomass yield (Tabatabaii et al., 2011). Choudhry and Malik (2000), and Sharif and Hussain (1993) also noted a significant increase in biomass yield of maize with K application over the control plots. The increase in biomass yield with K split application reflects the better growth and development of the plants due to more availability of nutrients throughout the growing period of maize (Asif et al., 2007; Amanullah et al., 2007). The increase in biomass yield of maize with application of cattle dung probably may be due to the improved soil physico-chemical properties, enhanced soil nutrients and organic matter content, improved soil pH and CEC and the improved activity of soil organisms (Fageria, 2009; Hidayatullah et al., 2013). Haghighat et al. (2013) found that sweet corn biomass yield increased with application of cattle manure. Several other researchers revealed that organic manuring increased the vegetative growth and biomass production Ibeawuchi et al., 2007; Roy and Hore, 2010; Dinesh et al., 2010; Mahadi et al. (2012).

Harvest index was higher when K was applied at rate of 90 kg ha^{-1}. The increase in harvest index with higher K level was attributed to the more dry matter partitioning into the reproductive parts (ears) of maize. The increase in K level increased yield and yield components of maize (1st paper submitted from this study) and hence the harvest index was also increased with increase in K level. Because the increase in grain yield and yield components had positive relationship with harvest index in maize crop (Amanullah, 2014). In our experiment both field under with and without cattle dung had statistically the same harvest index. However, the field under cattle dung produced relatively higher harvest index than the field where no cattle dung was applied. Improvement in harvest index was reported earlier by Fallah et al. (2007) and Mahadi et al. (2012) in maize, and Haghighat et al. (2013) in sweet corn. Ogbonna and Obi (2005) reported that increase in organic manure application resulted in high dry matter partitioning and therefore increased grain yield and higher harvest index.

CONCLUSIONS

The potassium (K) treated plots had better performance in terms of improved leaf number and mean leaf area, dry matter partitioning, biomass yield and harvest index than control (no K applied). Application of K at the highest rate of 90 kg K ha^{-1} improved leaf number and mean leaf area, dry matter partitioning, biological yield and harvest index of maize. Application of K in two equal splits (50% at sowing and 50% at V9 stage) improved leaf number and mean leaf area, dry matter partitioning, biomass yield and harvest index. The experiment under cattle manure (5 t ha^{-1}) had better growth (more leaf number and mean leaf area), higher dry matter partitioning into different plant parts, and higher biomass yield than the experiment where cattle manure was not applied. Application of K at the highest rate of 90 kg ha+ in two equal splits (50% at sowing and 50% at V9 stage) along with cattle manure (5 t ha^{-1}) could increase crop growth and productivity under calcareous soils.

Author contributions

A.: Designed the study, supervised the research project. A. I.: Conducted the field experiment, took the data, did the analysis, wrote the report and this manuscript. M. I.: Downloaded related literature for this manuscript and and also corrected the article.

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