__Original Research Article__

GROWTH OF MAIZE IN RESPONSE TO *IN-SITU* GREEN MANURING

ABSTRACT

A field study was conducted at College farm, College of Agriculture, Rajendranagar to evaluate the effect of *in-situ* green manuring on the growth of *rabi* maize and the proportion up to which it can compensate nitrogen application at tasseling stage with eight treatments involving *in-situ* green manuring at 45 DAS and variable application of nitrogen split scheduled from 10 – 60 kg ha^{-1} at tasseling stage besides farmers practice randomized and raised in three replications. The results of the study indicated that at 30 and 60 DAS plant height, leaf area, SPAD and dry matter content did not vary significantly as all the treatments received equal doses of recommended nitrogen @ 60 kg ha^{-1} at the time of sowing and 30 DAS. However, at 90 DAS and harvest equivalent and higher plant height, leaf area, SPAD and dry matter values obtained in the treatments involving along with the variable application of nitrogen split in 30 (T_4), 40 (T_5), 50 (T_6) and 60 (T_7) kg ha^{-1} at tasseling stage.

1. INTRODUCTION

Maize is the most widely distributed crop in the world. In Indian Agriculture, maize occupies a prominent position. Maize is the fourth major crop of Telangana state. Maize being an exhaustive crop has very high nutrient demand hence, the role of balanced and adequate nutrition is recognized as one of the important factors in realizing the maximum yield of maize. The improved maize hybrids need a high amount of nitrogen for maximum exploitation of their potential to produce yields. Around 240 kg ha^{-1} of N is recommended for maize during *rabi* to explore its fullest potential for higher yields. In the maize production system nitrogen management is one of the main concerns because most of the nitrogen will be lost through leaching, volatilization, immobilization, denitrification, erosion and adsorption on clay colloids (Hofman and Cleemput 2004).

The integration of organic and inorganic sources of nutrients not only supplies essential plant nutrients but also enhances nutrient use efficiency and subsequently reduces environmental pollution (Ahmad *et al*., 1996). Green manuring is an inevitable approach in the coming years for sustainable agriculture. The addition of organic matter through green manures has good results for fertilizer use efficiency and nutrient availability (Abrol *et al*., 1988). *In-situ* sunhemp mulch accumulates an average of 3-4 t ha^{-1} organic matter which contains 2.5 % N, 0.3 % P and 1.3 % K. *In-situ,* intercropped green manure crop of sunhemp generates a high amount of organic matter with a positive effect on the soil's physical, chemical and biological properties, which are often deteriorated under intensive cultivation (Channagouda *et al*., 2015).

Therefore, to achieve enhanced and sustained yield of *rabi* maize through improvement of soil productivity, there is a need to work out proper nitrogen management techniques by inclusion of green manure crops.

2. MATERIALS AND METHODS

The study was conducted during *rabi*, 2022 at college farm, College of Agriculture, Rajendranagar, Hyderabad. The experiment was laid out in a randomized block design consisting of eight treatments *viz*., T_1: *In-situ* green manuring of Sunhemp at 45 DAS (GM) + 0 kg N ha^{-1} at tasseling (T) stage, T_2: GM + 10 kg N ha^{-1} at T, T_3: GM + 20 kg N ha^{-1} at T, T_4: GM + 30 kg N ha^{-1} at T, T_5: GM + 40 kg N ha^{-1} at T, T_6: GM + 50 kg N ha^{-1} at T, T_7: GM + 60 kg N ha^{-1} at T, T_8: Farmer's Practice (Application of RDF without green manuring) replicated thrice on clay loam soil. Recommended nitrogen (240 kg ha^{-1}) was applied to the maize crop in four (4) splits at the time of sowing (basal), knee height, pre-tasseling and tasseling stages in the form of urea. The first 3 nitrogen splits were applied equally to all the treatments @ 60 kg N ha^{-1} per split, while the 4^{th} split was applied as per treatments. A uniform dose of 80 kg P_2O_5 and K_2O ha^{-1} was applied to maize in the form of single super phosphate and murate of potash respectively, at the time of sowing. The soil of the experimental site was alkaline in reaction with low organic matter, low soil available nitrogen, low soil available phosphorous and potassium. The crops (Maize and Sunhemp) were sown on 15^{th} November 2022. Maize seeds were sown in paired rows and two rows of sunhemp were accommodated between the maize pairs. The climate of the experimental region is semi-arid (dry). The mean weekly maximum temperature during the experiment ranged from 28.4 to 34.2 ℃ while the mean weekly minimum temperature ranged from 10.8 to 18.2 ℃. The mean weekly relative humidity during the experiment at 0730 and 1400 hrs fluctuated between 75 to 92 per cent and 19 to 59 per cent, respectively. A total rainfall of 8.2 mm was received during the experiment which did not account for a single rainy day. The mean sunshine hours extended from 4.4 to 10.1 hours day^{-1}. The evaporative demand of the atmosphere as reflected by the pan evaporimeter (USWB Class A pan) during the crop growth varied from 2.4 to 5.4 mm day^{-1}. The wind speed stretched from 2.0 to 4.1 km hr^{-1}. Owing to *in-situ* green manuring and variable nitrogen application at the tasseling stage the growth of maize in terms of plant height, leaf area, SPAD and dry matter accumulation has been recorded and presented in the following sections.

3. RESULTS AND DISCUSSION

3.1 Growth parameters

3.1.1 Plant height

The plant height of maize was recorded at 30-day intervals from sowing to harvest. The data on the plant height at different intervals is presented in Table 1. An overview of plant height in maize indicated that supplementing a part of recommended nitrogen with green manure at the tasselling stage had a significant effect on crop performance later to 60 DAS. Maize's height increased with the advancement of crop growth. The increment was steep up to 60 DAS, later it was gradual towards harvest.

Observation of plant height at 30 DAS indicated that the plant height did not vary significantly due to the treatments, T_1 to T_8 as the crop in all the treatments received basal dose of recommended nitrogen @ 60 kg ha^{-1}. The plant height at 30 DAS ranged from 68.4 - 73.1 cm. An observation of the data indicated that though the green manure crop, sunhemp was raised between the crop rows, it did not pose enough competition to maize to alter its height as no difference in plant height was noted in the treatments with green manure (T_1-T_7) and without green manure (T_8) at 30 DAS.

The plant height of maize escalated from an average of 70.5 cm at 30 DAS to 176.6 cm at 60 DAS attributed to the crop's inherent nature of vigorous growth in response to nutrients and irrigation. The difference in plant height due to the incorporation of green manure was discreet at 60 DAS as all the treatments (T_1 - T_7) green manured at 45 DAS remained at par with plant heights ranging from 170.9 to 182.1 cm. However, these treatments varied significantly with the treatment that was not green-manured (T8) as it registered the lowest plant height of 167.5 cm. Significant enhancement of plant height in all the green manure incorporated treatments indicated that the process of decomposition of incorporated green manure has been initialized but the nutrient release might not be sufficient enough to bring remarkable differences between the treatments T_1 to T_7. In treatment T_8, the crop lacked the additional benefit that green manuring can incur to boost crop growth, hence registering lesser plant height.

The differences in plant height were conspicuous by 90 DAS. *In-situ* green manuring at 45 DAS and variable application of nitrogen split at the tasselling stage have brought about significant differences in the plant height of maize. Observation of data at 90 DAS indicated that the plant height was higher (201.0 cm) in the T_7 treatment involving *in-situ* green manuring in addition to the recommended split N application @ 60 kg ha^{-1}. This treatment, however, was on par with treatments T_4, T_5, and T_6 wherein nitrogen split at the tasselling stage was downsized by 30 (T_4), 20 (T_5), and 10 (T_6) kg ha^{-1}, respectively in addition to *in-situ* green manuring and T_8 treatment involving recommended N application with no green manuring. The plant height in the above treatments ranged from 193.7 to 198.3 cm. On the other side, the treatments involving *in-situ* green manuring and downsized application of nitrogen by 60 (T_1), 50 (T_2), and 40 (T_3) kg ha^{-1} at the tasselling stage had registered shorter plants with plant heights ranging from 183.4 to 187.5 cm.

The plant height data noted at harvest was in line with 90-day data with equivalent and higher plant heights in T_4, T_5, T_6, T_7, and T_8 treatments. The plant height in these treatments ranged from 199.5 to 207.1 cm. While the lowest plant heights were reported by T_1, T_2, and T_3 treatments ranging from 187.8 to 192.3 cm.

From the above data, it can be inferred that *in-situ* green manuring has compensated up to 30 kg N ha^{-1} at the tasselling stage and significantly enhanced the plant height equivalent to the crop that was not green manured. The treatments T_4, T_5, T_6, and T_7, though applied with higher nitrogen at the tasselling stage in addition to green manuring did not show prominent differences in plant height which may be ascribed to presumable loss in applied nitrogen which however was not recorded. Similar, reults were also reported by Haroon *et al*. (2020).

Table 1. Plant height (cm) of maize in response to *in situ* green manuring and nitrogen scheduling at tasseling stage

Treatments	30 DAS	60 DAS	90 DAS	Harvest
T_1: *In situ* green manuring of Sunhemp at 45 DAS (GM) + 0 kg N ha^{-1} at tasseling (T) stage	68.4	171	183	188
T_2: GM + 10 kg N ha^{-1} at T	69.0	176	185	190
T_3: GM + 20 kg N ha^{-1} at T	69.9	176	188	192
T_4: GM + 30 kg N ha^{-1} at T	71.1	182	198	204
T_5: GM + 40 kg N ha^{-1} at T	70.1	178	197	202
T_6: GM + 50 kg N ha^{-1} at T	70.7	180	198	203
T_7: GM + 60 kg N ha^{-1} at T	71.6	182	201	207
T_8: Farmer's Practice (Application of RDF without green manuring)	73.1	167	194	200
S.Em ±	**1.58**	**3.97**	**3.37**	**3.47**
CD (P=0.05%)	**NS**	**12.0**	**10.2**	**10.5**

3.1.2 Leaf area

Observations on leaf area were also noted at 30-day intervals during the crop growing season. The data recorded on the leaf area presented in Table 2 was in line with the data on plant height. No conspicuous differences in leaf area were observed up to 60 DAS. The effect of *in-situ* green manuring and variable application of nitrogen split at the tasselling stage was endorsed at 90 DAS and harvest.

The leaf area of maize did not vary significantly among the treatments at 30 DAS. At this stage, the leaf area ranged from 531 to 570 cm^2. As all the treatments received equal doses of basal nitrogen they performed equivalently. As with plant height, no competition effect of green manure on maize was noted with regards to leaf area in T_1 - T_7 treatments. Maize was sown in paired rows to accommodate two rows of green manure outlining the entire system with crop and green manure rows spaced at 30 cm distance which eventually nullified the competition effect between the crop and green manure.

Treatment differences remained insignificant at 60 DAS. The leaf area at this stage ranged from 2799 to 3040 cm^2. Owing to its vigorous growth, the leaf area of maize increased three folds of that observed at 30 DAS. However, this vigorous growth is bestowed on the crop's inherent character but not the treatment effect. Though the green manure crop was incorporated *in-situ* at 45 DAS, it did not have a significant effect on the leaf area which might be attributed to insufficient release of nutrients by the decomposing green manure to bring about remarkable differences among the treatments.

Unlike the data at 30 and 60 DAS, the data at 90 DAS showed significant variation among the treatments for leaf area. At this stage of the crop, the leaf area ranged from 3841 to 4094 cm^2. The treatments, T_4, T_5, T_6, and T_7 had put forth statistically equivalent and higher leaf areas of 4062, 3967, 3982, and 4094 cm^2, respectively. In the above treatments, nitrogen split to be applied at the tasselling stage is contrived to compensate 30, 20, 10, and 0 kg ha^{-1}, respectively with *in-situ* green manuring. From the above data, it can be inferred that green manuring has compensated up to 30 Kg N ha^{-1} at the tasselling stage to put forth maximum plant growth in terms of leaf area. The differences among the remaining treatments (T_1, T_2, T_3, and T_8) have narrowed down making them on par with the lowest leaf areas ranging from 3842 to 3908 cm^2. A similar trend was observed at harvest. The treatments, T_4, T_5, T_6, and T_7 registered higher and comparable leaf areas of 4075, 3990, 3998, and 4105 cm^2, respectively. The remaining treatments (T_1, T_2, T_3, and T_8) reported lower leaf areas ranging from 3857 to 3921 cm^2. Similar results were also reported by Muttana *et al*. (2017).

Table 2. Leaf area (cm^2) of maize in response to *in situ* green manuring and nitrogen scheduling at tasseling stage

Treatments	30 DAS	60 DAS	90 DAS	Harvest
T_1: *In situ* green manuring of Sunhemp at 45 DAS (GM) + 0 kg N ha^{-1} at tasseling (T) stage	531.1	2799.5	3841.6	3857.3

T_2: GM + 10 kg N ha^{-1} at T	538.9	2830.3	3847.7	3859.0
T_3: GM + 20 kg N ha^{-1} at T	543.8	2905.6	3903.2	3906.0
T_4: GM + 30 kg N ha^{-1} at T	558.6	3034.7	4062.2	4075.1
T_5: GM + 40 kg N ha^{-1} at T	551.6	2951.4	3967.8	3990.5
T_6: GM + 50 kg N ha^{-1} at T	557.8	3016.0	3981.6	3998.8
T_7: GM + 60 kg N ha^{-1} at T	562.8	3040.3	4093.9	4105.3
T_8: Farmer's Practice (Application of RDF without green manuring)	570.4	2771.6	3908.4	3921.2
S.Em ±	**13.5**	**92.5**	**46.4**	**43.5**
CD (P=0.05%)	**NS**	**NS**	**141**	**132**

3.1.3 SPAD

The data on the chlorophyll content of the plants measured by SPAD was presented in Table 3. The data obtained was in line with that obtained for plant height, leaf area and dry matter production. Up to 60 DAS, the plants did not show significant variations between the treatments in SPAD values. The difference among the treatments became conspicuous by 90 DAS which continued up to harvest.

The SPAD readings at 30 and 60 DAS ranged from 42.3 to 46.0 and 45.6 to 50.1, respectively. There was a marginal increment in the SPAD readings from 30 to 60 DAS indicating advancement in crop growth. However, as the crop approached 90 DAS, the SPAD values dropped from 34.0 to 38.5 indicating initiation of leaf senescence and mortality.

Observation of the crop at 90 DAS indicated significant differences in SPAD values owing to green manuring and variable nitrogen application at the tasseling stage. The treatments T_4, T_5, T_6 and T_7 involving green manuring at 45 DAS and nitrogen split fertilization at the tasseling stage @ 30, 40, 50 and 60 kg ha^{-1}, respectively had accounted for on par and higher SPAD values ranging from 37.2 to 38.5. While, the remaining treatments involving lesser application of nitrogen split at tasseling stage @ 0, 10 and 20 kg ha^{-1}, respectively in addition to green manuring (T_1, T_2 and T_3 respectively) and the treatment with 60 kg N ha^{-1} at the tasseling stage without green manuring (T_8) reported comparably lesser SPAD values ranging from 34.0 to 36.8. the above result is in tune with the plant height, leaf area and dry matter production data indicating T_4, T_5, T_6 and T_7 as the best treatments owing to the vigorous growth of the crop and underlining that an amount of 30 kg N ha^{-1} at the tasseling stage can be substituted with green manuring for effective crop growth.

As the crop approached maturity, the SPAD values dropped drastically and ranged from 17.6 to 19.9. However, the treatments T_4, T_5, T_6 and T_7 continued their supremacy and reported higher SPAD values ranging from 19.0 to 19.9. While the treatments T_1, T_2, T_3 and T_8 remained low with on-par SPAD values ranging from 17.6 to 18.5. Similar results also reported by Islam *et al*. (2019).

Table 3. SPAD of maize in response to *in situ* green manuring and nitrogen scheduling at tasseling stage

Treatments	30 DAS	60 DAS	90 DAS	Harvest
T_1: *In situ* green manuring of Sunhemp at 45 DAS (GM) + 0 kg N ha^{-1} at tasseling (T) stage	42.3	46.4	34.0	17.6
T_2: GM + 10 kg N ha^{-1} at T	42.5	46.7	35.7	18.2
T_3: GM + 20 kg N ha^{-1} at T	42.9	47.0	36.7	18.3
T_4: GM + 30 kg N ha^{-1} at T	44.5	49.0	37.5	19.5
T_5: GM + 40 kg N ha^{-1} at T	43.2	47.3	37.2	19.0
T_6: GM + 50 kg N ha^{-1} at T	44.0	48.3	37.2	19.4
T_7: GM + 60 kg N ha^{-1} at T	45.8	50.1	38.5	19.9
T_8: Farmer's Practice (Application of RDF without green manuring)	46.0	45.6	36.8	18.5
S.Em ±	**1.39**	**1.55**	**0.50**	**0.41**
CD (P=0.05%)	**NS**	**NS**	**1.52**	**1.24**

3.1.4 Dry matter

Accumulation of dry matter is the primary indicator of the effect of environmental, soil, and cultural (inputs given) factors that the plant thrived on for its growth and development. Marking down the dry matter accumulation by a crop at regular intervals assists in contemplating its performance in response to inputs received. Hence dry matter accumulation acknowledging green manuring and variable nitrogen application at the tasselling stage in the present study was noted at 30-day intervals. The data on dry matter accumulation presented in Table 4 indicated significant differences only later to 60 DAS. The visible effect of green manuring at 45 DAS and variable N application at the tasselling stage was noted by 90 DAS which continued to harvest.

The dry matter accumulation in maize was comparable among the treatments both at 30 and 60 DAS. As the treatment imposition is scheduled only at 45 DAS, and the crop in all the treatments received an equal dose of nitrogen as basal and at 60 DAS, the dry matter accumulation remained at par among the treatments. Also, from the above data it can be understood that sunhemp did not pose any competition to maize for nutrients and irrigation which might be the fact that they are spaced equidistantly owing to paired row planting of maize. The dry matter production at 30 and 60 DAS ranged from 584-636 and 7728-8427 kg ha^{-1}, respectively. The dry matter production of the crop increased 28-fold towards harvest than that at 30 DAS.

At 90 DAS, significant differences between the treatments in response to green manuring at 45 DAS and variable application of nitrogen at the tasselling stage were noted. The dry matter production of maize at this stage ranged from 10006 to 11554 kg ha^{-1}. Comparably taller plants with higher leaf areas in the treatments, T_4-T_7 might have aided in the inception of a larger amount of solar radiation, subsequent assimilation, and accretion of higher dry matter. The above treatments were *in-situ* green manured at 45 DAS and variably applied with nitrogen at the tasselling stage @ 30, 40, 50, and 60 kg ha^{-1}, respectively. The rest of the treatments, T_1, T_2, T_3, and T_8, with dry matter accumulation of 10006 to 10305 kg ha^{-1} remained low.

Corresponding to the above data, the dry matter production at harvest was also higher and comparable between T_4 and T_7 treatments ranging from 17464 to 18023 kg ha^{-1}. On the contrary, T_1, T_2, T_3, and T_8 were inferior with lower dry matter contents (16371-16880 kg ha^{-1}). Green manuring scheduled to compensate 60, 50 and 40 kg ha^{-1} in T_1, T_2 and T_3 treatments, respectively might not have sufficiently met the requirement of the crop for growth and metabolism resulting in lesser accretion of dry biomass. Though the differences between the above and the best treatments appeared to be marginal, they were significant enough to vary the dry matter accumulation. As mentioned in 4.1, the treatment T_8 missed out on the additional benefit of green manuring, hence registering lesser dry matter in spite of the application of the recommended package of nutrients. The best performance of T_4, T_5, T_6, and T_7 treatments may be vested on top dressing the green manured crop with nitrogen split at the tasselling stage @ 30, 40, 50, and 60 kg ha^{-1}, respectively. From this result, it can be deduced that at the tasselling stage, the crop can be recompensated with green manuring up to 30 kg ha^{-1} meeting the needs of both crop and microbial populations in the microenvironment. Nitrogen application excess of 30 kg ha^{-1} applied in addition to green manuring may not bring additional benefit to the crop instead may be prone to loss, hence the equi-performance of the treatments, T_4, T_5, T_6, and T_7. Similar results also reported by kholoud *et al*. (2019).

Table 4. Dry matter (kg ha^{-1}) of maize in response to *in-situ* green manuring and nitrogen scheduling at tasseling stage

Treatments	30 DAS	60 DAS	90 DAS	Harvest
T_1: *In situ* green manuring of Sunhemp at 45 DAS (GM) + 0 kg N ha^{-1} at tasseling (T) stage	584	7863	10006	16371
T_2: GM + 10 kg N ha^{-1} at T	592	7953	10116	16526
T_3: GM + 20 kg N ha^{-1} at T	598	7979	10281	16795
T_4: GM + 30 kg N ha^{-1} at T	620	8278	11232	17949
T_5: GM + 40 kg N ha^{-1} at T	604	8013	10879	17465
T_6: GM + 50 kg N ha^{-1} at T	606	8124	11054	17628
T_7: GM + 60 kg N ha^{-1} at T	625	8427	11554	18024
T_8: Farmer's Practice (Application of RDF without green manuring)	636	7728	10305	16880
S.Em ±	**17.9**	**239**	**350**	**331**
CD (P=0.05%)	**NS**	**NS**	**1063**	**1005**

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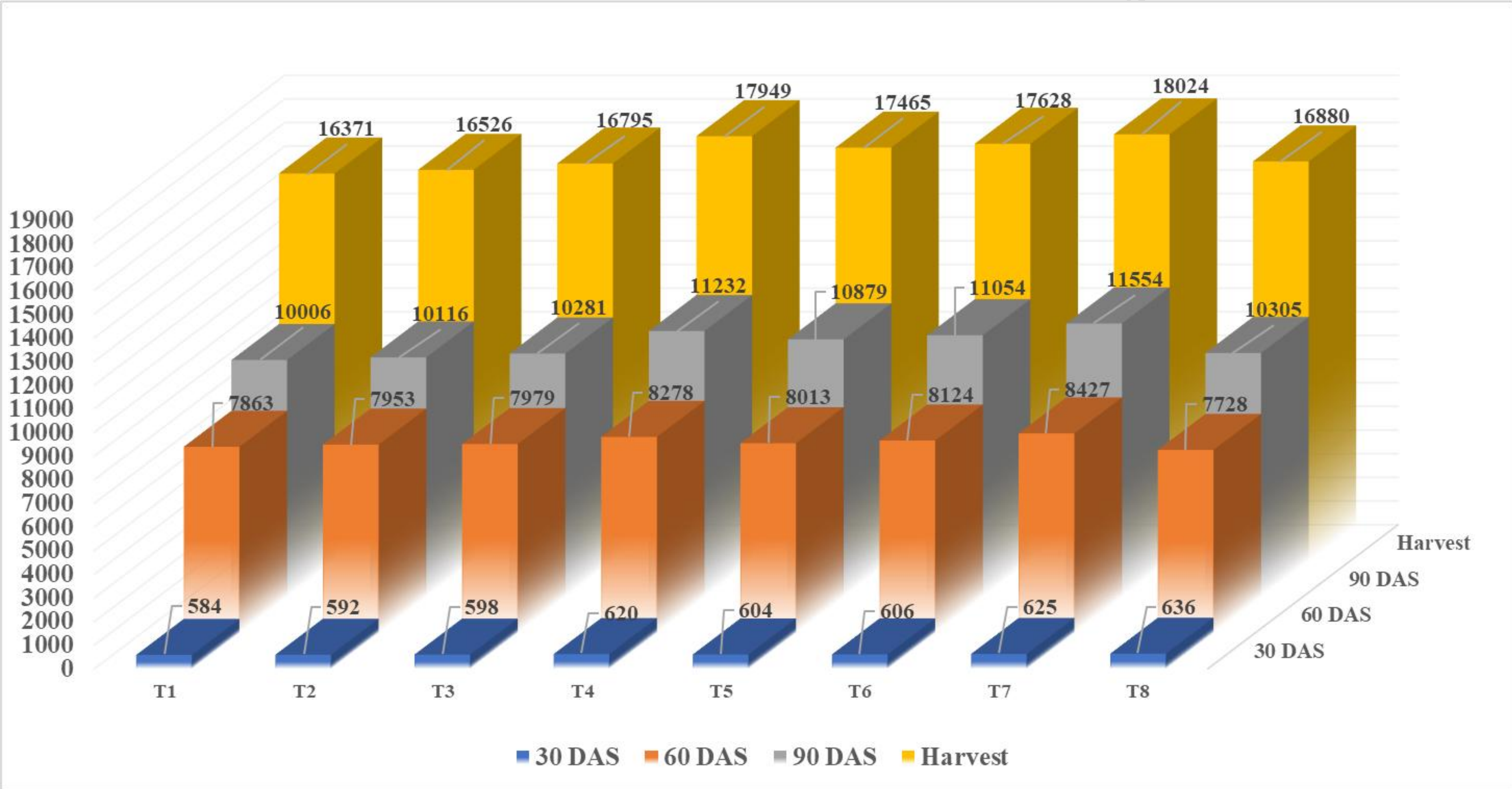

Fig. 1. Dry matter (kg ha^{-1}) of maize in response to *in situ* green manuring and nitrogen scheduling at tasseling stage

CONCLUSION

Based on the research results of the present study it can be concluded that at tasseling stage, the crop can be compensated with green manuring up to 30 kg ha^{-1} meeting the nitrogen needs of the crop. Nitrogen application excess of 30 kg ha^{-1} applied in addition to green manuring may not bring benefits to the crop, instead may be prone to loss, hence equi-performance of the treatments T_4, T_5, T_6 and T_7.

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