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RESEARCH PAPER

Impact of sowing windows and fertility levels on growth and yield of winter maize in Northern Transitional Zone of Karnataka

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Abstract: A field experiment was conducted to study the response of winter maize to sowing windows and fertility levels at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka on medium to deep black soils during 2019-20. The experiment comprised of two factors, *viz*., five windows of sowing and three fertility levels and was laid out in randomized complete block design with factorial concept with three replications. Planting of winter maize during first week of October recorded significantly higher grain yield (87.87 q ha^{-1}) and stover yield (122.0 q ha^{-1}) and was found on par with sowing during second week of October. Among fertility levels, significantly higher grain yield (83.20 q ha^{-1}) and stover yield (119.5 q ha^{-1}) were recorded with application of 200 % recommended dose of fertilizer and was found on par with application of 150 % recommended dose of fertilizer. In treatment combinations, higher grain yield (91.42 q ha^{-1}) and stover yield (130.5 q ha^{-1}) were during first week of October with application of 200 % recommended dose of fertilizer and was found on par with sowing during second week of October along with application of 200 % recommended dose of fertilizer and sowing during first week of October with application of 150 % recommended dose of fertilizer. Similar trend was observed with respect to growth *viz.*, plant height, leaf area per plant, leaf area index, absolute growth rate, crop growth rate and total dry matter production and yield attributes *viz.*, cob length, cob girth, number of grain rows per cob and test weight. Economic analysis showed that planting of winter maize during first week of October with application of 150 % recommended dose of fertilizer recorded significantly higher gross returns (₹163646 ha^{-1}) and net returns (₹ 99,121 ha^{-1}) as compared to all other treatment combinations.

Key words: Growth, Maize, Nutrients, Winter

Introduction

Maize (*Zea mays* L.) is one of the important cereal crop which belongs to Poaceae family stands first with respect to production in the world. In India, it ranks third after rice and wheat. Maize is called "Queen of cereals" as it is grown throughout the year due to its photo-insensitive character and highest genetic yield potential among the cereals. Globally it is grown on an area of 192.50 m ha with an annual production of 1,112.40 m t at a productivity of 5742 kg ha^{-1} (Anon., 2019a). In India, currently, it is cultivated on an area of 9.38 m ha with a production of 28.752 m t and at a productivity of 3065 kg ha^{-1} (Anon., 2019). In Karnataka, maize is grown in an area of 1.3 m ha with a production of 3.85 m t and a productivity of 2948 kg ha^{-1} (Anon., 2019b).

Maize is predominantly a *kharif* season crop but in past few years *winter* maize has gained a significant place in total maize production in India. Cultivation during *winter* is becoming a common practice in Peninsular India (Andhra Pradesh, Karnataka and Tamil Nadu), as well as in north- eastern plains. In Karnataka *winter* maize is grown in an area of 0.124 m ha with a production of 0.46 m t and productivity of 3710 kg ha^{-1} and stands first in India with a share of 14.8 per cent in total area and second with respect to total maize production with annual share of 13.6 per cent for the country (Anon., 2019b). According to Singh *et al.* (2012) though the crop favourably responds to better crop management both in *kharif* and *winter* season, the erratic rainfall pattern of the south-west monsoon comes in the way of timely field operations of *kharif* season. Due to absence of major environmental impediments in *winter,* the desired field operations can be planned and executed at the most desired time. Moreover, the various environmental factors, including absence of any major disease and insect- pest in this season, helps in realizing better profits. Hence there is immense potential to increase the area under *winter* maize cultivation.

The optimum date of sowing is important for winter maize so that the crop grown can complete its life cycle under optimum environmental conditions. Early planting is usually favoured. In order to maximise yield, sowing is very necessary at the appropriate time, as delay in the planting date will lead to a linear decrease in grain and stover yields (Anapalli *et al.*, 2005). The extent of reduction in yield through delayed sowing however varies with the location. Hence, experiment was conducted to explore the most congenial sowing period in Southern India.

There are several factors affecting winter maize production and productivity; however, managing the fertilizer is one of the most important factors affecting maize growth and yields. Maize expresses its full yield potential only when there are adequate nutrients in soil. And hence it requires intelligent fertilizer programme. Early sowing of maize can significantly improve grain yields, but other practises such as higher fertility may also boost grain yields.

Material and methods

Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka is situated at 15°26' N latitude and longitude of 75°07' E with an altitude of 678 m above the mean sea level (MSL). During the *winter* cropping season of maize (2019), a total rainfall of 352.0 mm was received out of which 323.2 mm was received during the sowing month (October). The highest and the lowest maximum temperature were 31.8 ºC (February) and 28.5 ºC (December), respectively while the respective highest and the lowest minimum temperature were 15.5 ºC (January) and 20.3 ºC (October) respectively were recorded during cropping period. The mean relative humidity ranged from 49.4 per cent in February to 79.8 per cent in October during cropping period The soil of the experimental site was black clay in texture with pH of 7.6 and electrical conductivity of 0.33 dS m^{-1}. The soil was medium in organic carbon (0.55 %) and low in available nitrogen (261 kg ha^{-1}) and medium in available phosphorous (31.5 kg ha^{-1}) and medium in available potassium (289 kg ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with factorial concept with three replications having fifteen treatment combinations. The experiment comprised of two factors, *viz*., sowing windows (1st week of October, 2nd week of October, 3rd week of October, 4th week of October and 5th week of October) and fertility levels (100 % RDF, 150 % RDF and 200 % RDF). The RDF applied was 150 kg N ha^{-1}, 65 kg P_2O_5 ha^{-1} and 65 kg K_2O ha^{-1}. Maize hybrid used was '900 M Gold'. The land was ploughed once followed by tillage with cultivator and harrowed twice to bring the soil to fine tilth. Weeds and leftover residues were cleared from the experimental area after the harvest of previous crop. Well decomposed FYM @ 10 t ha^{-1} was incorporated into soil two weeks prior to sowing to all other treatment plots. The plots were laid out as per the plan of layout of the experiment. Seeds were sown at a spacing of 60 cm x 20 cm with seed rate of 20 kg ha^{-1}. The lines were opened with the help of marker and the seeds were hand dibbled at a depth of 4-5 cm and covered with soil. First to fifth dates of sowing were 08-10-2019, 12-10-2019, 18-10-2019, 28-10-2019 and 06-11-2019 respectively. The nutrients *viz.,* nitrogen, phosphorus and potassium was applied @ 150 kg N ha^{-1}, 65 kg P_2O_5 ha^{-1} and 65 kg K_2O ha^{-1} for fertility level of 100 % RDF. All treatments received $FeSO_4$ and $ZnSO_4$ each @ of 25 kg ha^{-1} commonly. Half of recommended nitrogen and 100 per cent of recommended phosphorus and potassium were applied as basal dose at the time of sowing and remaining 50 per cent nitrogen was applied in two equal splits as per the treatments at 30 and 60 days after sowing. First intercultivation was done at 30 days after sowing. Hand weeding was done at 30 and 55 days after sowing to check the weed growth and to keep the plots free from weeds during the cropping period in all the dates of sowing. Crop was protected against fall army worm and stem borer with the spray of proclaim @ of 0.5 g $litre^{-1}$. The rainfall received during respective sowing windows ensured sufficient soil moisture for germination, emergence and early establishment of seedlings for all dates of sowing. Rainfall during the crop growth period was received in the month of October (323.2 mm) and November (21.0 mm) and rest of the season crop was raised with irrigation by following critical stage approach. The experiment was purely under irrigated condition hence crop didn't suffer due to moisture stress during crop period.

Results and discussion

Response of *winter* maize to sowing windows

First week of October sowing significantly recorded higher grain yield and stover yield (87.8 q ha^{-1} and 122.0 q ha^{-1}, respectively) and it was on par with sowing during 2nd week of October (86.4 q ha^{-1} and 119.8 q ha^{-1} respectively). Sowing during October 1st week recorded 1.65, 8.04, 18.17 and 30.53 per cent linear increase in grain yield compared to sowing during 2nd, 3rd, 4th week of October and 1st week of November respectively. (Table 2 and Fig. 2). Significantly higher grain yield obtained from October 1st week sowing was attributed to significant improvement in yield characters *viz.*, number of grain rows cob^{-1} (16.9), cob length (17.0 cm), girth of cob (16.5 cm) and 100 seed weight (35.38 g) (Table 2). Similar results were also obtained by Khan *et al*. (2009), who reported that late sowing would lead to a lesser row number and less grain numbers in the rows of maize. Further, increase in grain yield and yield attributes in first week of October was due to improved growth parameters *viz.,* plant height (224.8 cm), leaf area (42.43 dm^2 $plant^{-1}$), leaf area index (3.54), absolute growth rate (AGR) (1.72 g day^{-1}), crop growth rate (CGR) (14.35 g m^{-2} day^{-1}) (Table 1) and total dry matter production (283.13 g $plant^{-1}$) (Fig. 1a) as a result of higher accumulation of growing degree days (GDD) compared to delayed sowing. Swetha (2017) reported that early sowing of maize recorded higher grain yield compared to other delayed sowing due to higher accumulation of GDD, PTU and HTU. Similarly higher GDD accumulation was reported in early planted maize (Hugar, 2015).

There was optimum climatic condition (Maximum mean temperature 27.9 ºC and Minimum mean temperature 19 ºC in October Month) prevailed for crop sown during first and second week of October (early) sowing of *winter* maize while, delayed sowing recorded reduced growth in terms of leaf area and dry matter accumulation. Optimum temperature for maize germination is 21 ºC, for growth 32 ºC and for tasselling 25-30 ºC (Panda, 2010). Late sown crop experienced lower temperature than optimum (18 ºC for germination, 23 ºC for growth and 23 ºC for tasseling). Further, lesser availability of solar radiation (PTU) as a result of shorter day lengths in late sowing condition leads shorter growing period which reduced the vegetative growth, dry matter accumulation and finally the yield. Biswas *et al.* (2014) stated that grain yields were reduced as delayed planting led to early maturity which reduced the grain filling period. Environmental changes associated with different sowing windows (sunshine and temperature) have a modifying effect on growth and development of maize plants (Dekhane and Dumbre, 2017). In early planted maize, better photosynthesis was observed as evidenced by more leaf area index and accumulation of photosynthetes due to favourable climatic conditions. Similar results were obtained by Keerthi *et al.* (2017) who recorded higher dry matter production (80.9 q ha^{-1}) and green cob yield of sweet corn (18291 kg ha^{-1}) sown during October first fortnight. Time of

Table 1. Plant height, leaf area, leaf area index, total dry matter (TDM) at harvest and absolute growth rate (AGR), crop growth rate (CGR) at 90 DAS- at harvest as influenced by sowing windows and fertility levels in *winter* maize

Treatment	Plant height (cm)	Leaf area (dm^2 $plant^{-1}$)	Leaf area index	TDM production (g $plant^{-1}$)	AGR (g day^{-1})	CGR (g m^{-2} day^{-1})
Factor I: Sowing windows						
W_1: 1st week of October	224.8^{a}	42.43^{a}	3.54^{a}	280.13^{a}	1.72^{a}	14.35^{a}
W_2: 2nd week of October	223.5^{a}	41.52^{a}	3.46^{a}	273.91^{a}	1.68^{a}	14.00^{a}
W_3: 3rd week of October	212.8^{a}	34.94^{b}	2.91^{b}	252.78^{b}	1.63^{a}	13.62^{a}
W_4: 4th week of October	187.4^{b}	31.40^{c}	2.62^{c}	243.15^{bc}	1.62^{a}	13.55^{a}
W_5: 1st week of November	182.0^{b}	28.7^{c}	2.39^{c}	231.74^{c}	1.47^{a}	13.23^{a}
S.Em.±	3.58	0.80	0.07	3.97	0.08	1.65
Factor II: Fertility levels						
F_1: 100 % RDF	196.3^{b}	32.19^{c}	2.68^{c}	247.02^{b}	1.48^{a}	12.93^{a}
F_2: 150% RDF	208.7^{a}	35.68^{b}	2.97^{b}	256.42^{ab}	1.63^{a}	13.71^{a}
F_3: 200% RDF	213.1^{a}	39.52^{a}	3.29^{a}	265.57^{a}	1.75^{a}	14.60^{a}
S.Em.±	4.63	1.03	0.09	5.13	0.10	2.12
Interaction (W×F)						
W_1F_1: 1st week of Oct + 100 % RDF	215.8^{a-c}	39.01^{bc}	3.25^{bc}	271.15^{a-d}	1.58^{ab}	13.21^{a}
W_1F_2: 1st week of Oct + 150 % RDF	224.0^{ab}	42.30^{ab}	3.52^{ab}	278.03^{a-c}	1.70^{ab}	14.23^{a}
W_1F_3: 1st week of Oct + 200 % RDF	234.6^{a}	45.97^{a}	3.83^{a}	291.19^{a}	1.86^{a}	15.59^{a}
W_2F_1: 2nd week of Oct + 100 % RDF	216.2^{a-c}	38.41^{bc}	3.21^{bc}	265.36^{a-e}	1.59^{ab}	13.28^{a}
W_2F_2: 2nd week of Oct + 150% RDF	226.8^{ab}	40.26^{bc}	3.35^{bc}	273.71^{a-c}	1.62^{ab}	13.55^{a}
W_2F_3: 2nd week of Oct + 200 % RDF	227.5^{ab}	45.94^{a}	3.82^{a}	282.66^{ab}	1.81^{a}	15.34^{a}
W_3F_1: 3rd week of Oct + 100 % RDF	204.8^{b-e}	30.61^{d-f}	2.55^{d-f}	242.36^{d-g}	1.49^{ab}	12.48^{a}
W_3F_2: 3rd week of Oct + 150 % RDF	214.3^{a-d}	35.98^{cd}	2.99^{cd}	255.38^{b-f}	1.69^{ab}	14.14^{a}
W_3F_3: 3rd week of Oct + 200 % RDF	218.9^{a-c}	38.21^{bc}	3.18^{bc}	260.61^{b-f}	1.70^{ab}	14.24^{a}
W_4F_1: 4th week of Oct + 100 % RDF	173.1^{f}	27.23^{ef}	2.26^{ef}	234.56^{fg}	1.52^{ab}	12.72^{a}
W_4F_2: 4th week of Oct + 150 % RDF	193.7^{c-f}	31.76^{de}	2.64^{de}	242.93^{d-g}	1.60^{ab}	13.50^{a}
W_4F_3: 4th week of Oct + 200 % RDF	195.4^{c-f}	35.28^{cd}	2.94^{cd}	251.95^{c-f}	1.72^{ab}	14.43^{a}
W_5F_1: 1st week of Nov + 100 % RDF	171.9^{f}	25.73^{f}	2.14^{f}	221.66^{g}	1.23^{b}	12.96^{a}
W_5F_2: 1st week of Nov + 150 % RDF	184.7^{ef}	28.21^{ef}	2.35^{ef}	232.09^{fg}	1.55^{ab}	13.12^{a}
W_5F_3: 1st week of Nov + 200 % RDF	189.4^{de}	32.19^{de}	2.68^{de}	241.45^{e-g}	1.63^{ab}	13.61^{a}
S.Em.±	8.01	1.78	0.15	8.88	0.17	3.68

RDF: (150 kg N: 65 kg P_2O_5 : 65 kg K_2O ha^{-1})

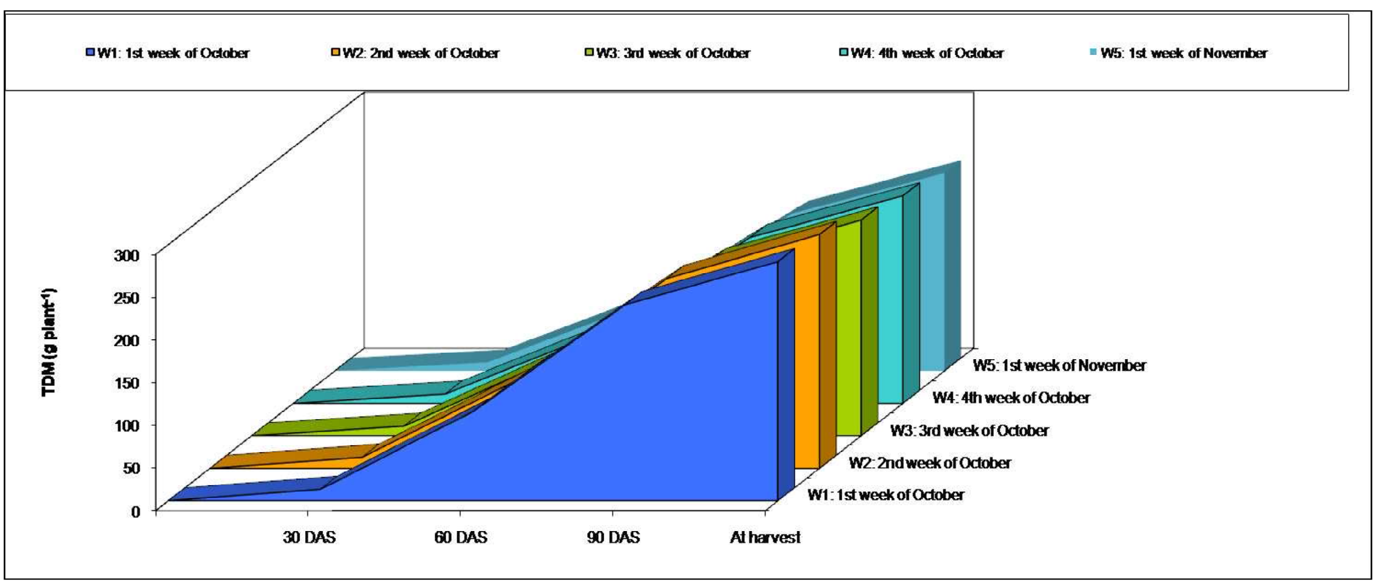

Fig. 4a. Total dry matter (TDM) production per plant at different growth stages of *winter* maize as influenced by sowing windows

sowing is a non monetary input which plays a significant role in production and productivity of crop. Similarly higher growth parameters were recorded with crop sown on 1st October, whereas delayed sowing reduced the growth parameters (Singh *et al.,* 2015). Late planting greatly affects the growth, development and productivity of maize plants. It brings changes in weather parameters such as temperature, solar radiation, humidity during crop season which responsible for changes in morphology, plant physiology and molecular level of plants. Thus sowing date has prime importance for crop production due to its variation in weather. Delayed sowing affects flowering, silking interval, photosynthesis, dry matter production and physiological maturity due to reduction in cumulative interception of photosynthetically active radiation (PAR). Late planting cause higher non-structural carbohydrate concentration in stem at mid grain filling stages because of low temperature exposure of crop limiting kernel growth and photosynthesis (Shrestha *et al.,* 2018).

Response of *winter* maize to fertility levels

Application of 200 % RDF recorded significantly higher grain and stover yield (83.19 q ha^{-1} and 119.5 q ha^{-1} respectively) and it was on par with application of 150 % RDF (80.2 q ha^{-1} and 114.1 q ha^{-1} respectively). Application 200 % RDF increased the grain yield by 3.71 % and 10.98 % compared to 150 % and 100 % RDF respectively. (Table 2 and Fig. 2). The increased grain yield was due to improved yield attributes *viz.,* length of cob (16.6 cm), girth of cob (16.0 cm) and test weight (35.12 g). (Table 2). Among several inputs essential for crop production, fertilizer management is of superlative importance. The same findings were reported by Jyothi *et al.* (2013) and they mentioned that higher nutrient uptake was recorded in higher fertilizer availability at rhizospere. Maize crop is a heavy feeder, requiring intelligent fertilizer programme which requires a lot of nitrogen, phosphorous, potassium and zinc. Maize responds better to higher level of nitrogen fertilizer, at a concentration that would normally cause lodging of other cereal crops. Adequate nitrogen should be supplied from germination to the flowering stage. Phosphorous should be applied as basal dose. It has beneficial effect on root growth and root development. Young seedlings do not require much potassium, but the rate of uptake jumps up to a peak level during three weeks prior to tasselling. It is essential for vigorous growth of the plant and for many other metabolic activities.

Further improved yield attributes was due to increased plant height (213.1 cm), leaf area (39.52 dm^2 $plant^{-1}$), leaf area index (3.29) and total dry matter production (265.57 g $plant^{-1}$) (Table 1 and Fig. 1b). Steady increase in AGR (1.75 g day^{-1}) and CGR

Table 2. Yield and yield attributes of *winter* maize as influenced by sowing windows and fertility levels

Treatment	Length of cob (cm)	Girth of cob (cm)	Number of grain rows per cob	Test weight (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})
Factor I: Sowing windows						
W_1: 1st week of October	17.0^{a}	16.5^{a}	16.9^{a}	35.38^{a}	87.87^{a}	122.0^{a}
W_2: 2nd week of October	16.4^{a}	16.2^{ab}	16.6^{ab}	35.16^{a}	86.44^{ab}	119.8^{ab}
W_3: 3rd week of October	16.3^{a}	15.1^{bc}	15.5^{bc}	34.37^{a}	81.33^{b}	113.2^{bc}
W_4: 4th week of October	15.9^{a}	14.6^{c}	15.4^{c}	34.03^{a}	74.36^{c}	107.5^{cd}
W_5: 1st week of November	13.5^{b}	13.1^{d}	15.1^{c}	33.38^{a}	67.32^{d}	103.3^{d}
S.Em.±	0.29	0.33	0.29	0.63	1.54	2.09
Factor II: Fertility levels						
F_1: 100 % RDF	15.1^{b}	14.1^{b}	15.5^{a}	33.72^{a}	74.97^{b}	105.9^{b}
F_2: 150% RDF	15.7^{b}	15.2^{a}	15.9^{a}	34.56^{a}	80.22^{a}	114.1^{a}
F_3: 200% RDF	16.6^{a}	16.0^{a}	16.3^{a}	35.12^{a}	83.20^{a}	119.5^{a}
S.Em.±	0.37	0.43	0.38	0.81	1.99	2.69
Interaction (W×F)						
W_1F_1: 1st week of Oct + 100 % RDF	16.2^{ab}	15.1^{b-e}	16.4^{a-c}	34.13^{a}	84.03^{a-c}	112.8^{b-g}
W_1F_2: 1st week of Oct + 150 % RDF	17.4^{a}	16.9^{a-c}	17.0^{ab}	35.81^{a}	88.14^{ab}	122.7^{a-c}
W_1F_3: 1st week of Oct + 200 % RDF	17.4^{a}	17.6^{a}	17.3^{a}	36.23^{a}	91.42^{a}	130.5^{a}
W_2F_1: 2nd week of Oct + 100 % RDF	15.7^{ab}	14.8^{b-e}	16.1^{a-c}	34.06^{a}	81.41^{a-d}	110.0^{c-g}
W_2F_2: 2nd week of Oct + 150% RDF	16.3^{ab}	16.5^{a-d}	16.7^{a-c}	35.5^{a}	87.83^{ab}	121.7^{a-d}
W_2F_3: 2nd week of Oct + 200 % RDF	17.3^{a}	17.2^{ab}	16.9^{ab}	35.9^{a}	90.07^{ab}	127.8^{ab}
W_3F_1: 3rd week of Oct + 100 % RDF	15.9^{ab}	14.5^{c-f}	15.3^{a-c}	33.6^{a}	78.59^{b-e}	106.9^{d-g}
W_3F_2: 3rd week of Oct + 150 % RDF	16.1^{ab}	15.0^{b-e}	15.5^{a-c}	34.5^{a}	82.17^{a-d}	114.8^{b-f}
W_3F_3: 3rd week of Oct + 200 % RDF	17.0^{a}	15.5^{a-e}	15.8^{a-c}	35.0^{a}	83.21^{a-c}	118.0^{a-e}
W_4F_1: 4th week of Oct + 100 % RDF	15.3^{a-c}	13.9^{ef}	15.1^{a-c}	33.8^{a}	69.13^{ef}	101.9^{fg}
W_4F_2: 4th week of Oct + 150 % RDF	15.6^{ab}	14.3^{d-f}	15.5^{a-c}	33.9^{a}	74.44^{c-e}	107.8^{c-g}
W_4F_3: 4th week of Oct + 200 % RDF	16.9^{a}	15.4^{a-e}	15.5^{a-c}	34.4^{a}	79.48^{b-e}	112.9^{b-g}
W_5F_1: 1st week of Nov + 100 % RDF	12.8^{d}	12.1^{f}	14.6^{h}	33.0^{a}	61.64^{f}	97.8^{g}
W_5F_2: 1st week of Nov + 150 % RDF	13.4^{cd}	13.0^{ef}	15.0^{gh}	33.1^{a}	68.50^{ef}	103.8^{e-g}
W_5F_3: 1st week of Nov + 200 % RDF	14.3^{b-d}	14.1^{d-f}	15.9^{d-f}	34.0^{a}	71.80^{d-f}	108.4^{c-g}
S.Em.±	0.64	0.74	0.65	1.41	3.45	4.66

RDF: (150 kg N : 65 kg P_2O_5 : 65 kg K_2O ha^{-1})

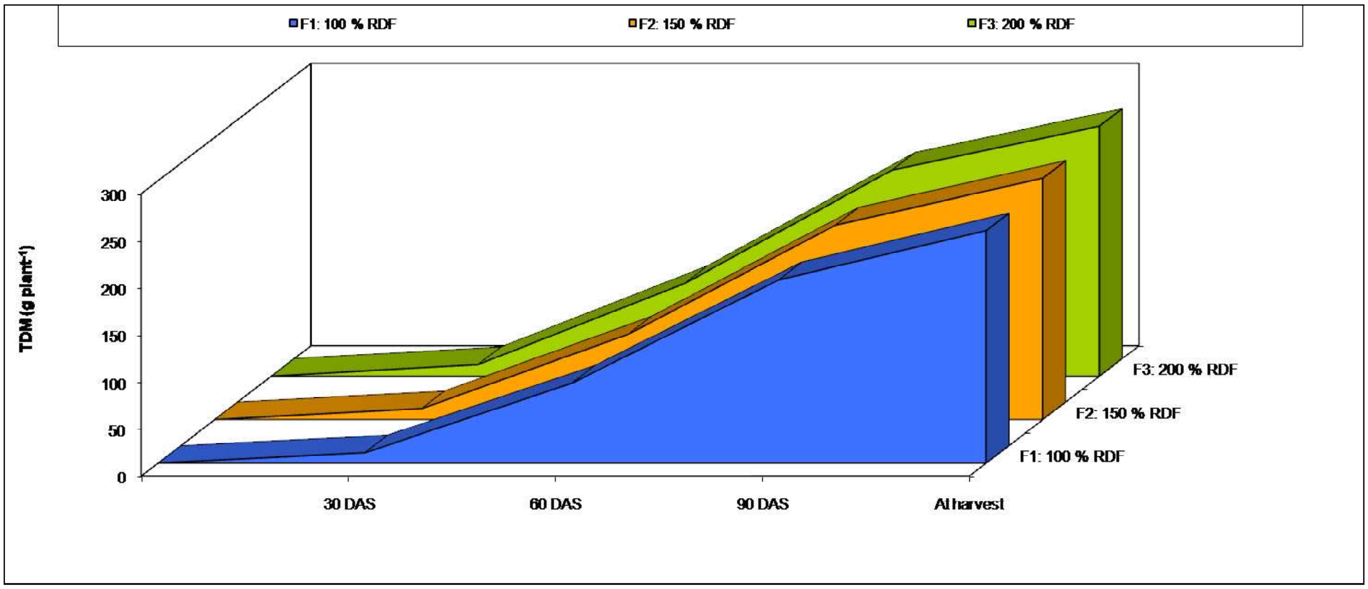

Fig. 4b. Total dry matter (TDM) production per plant at different growth stages of *winter* maize as influenced by fertility levels

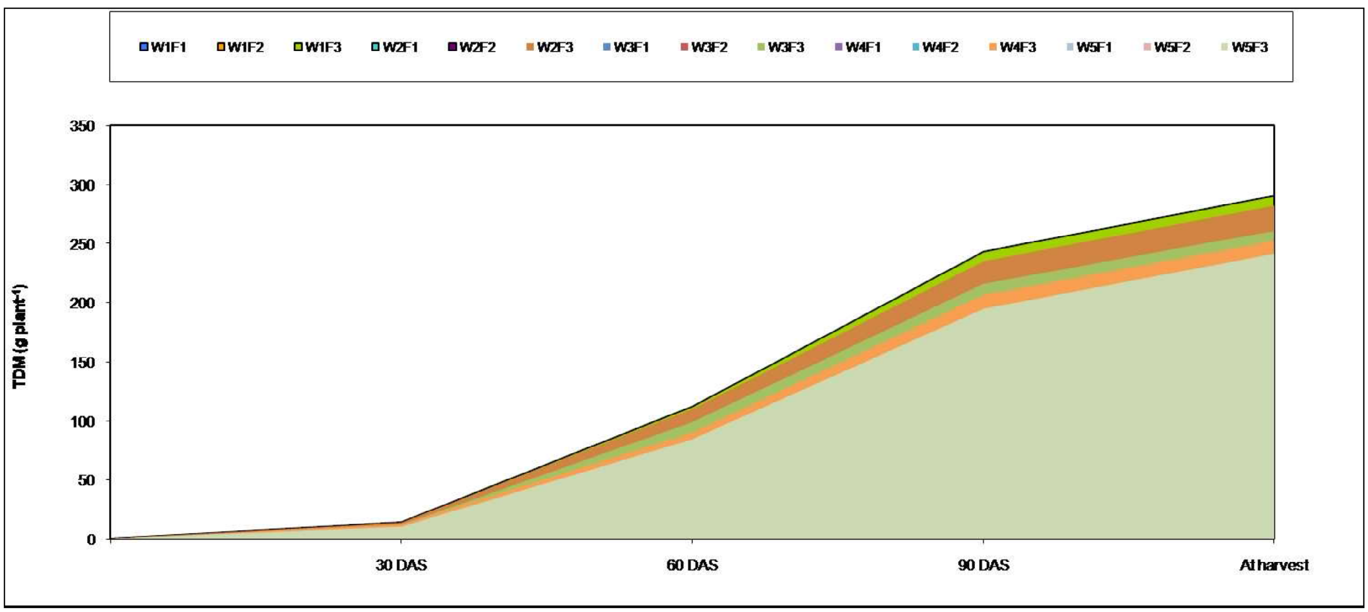

Fig. 4c. TDM production per plant at different growth stages of winter maize as influenced by sowing windows and fertility levels

(14.60 g m^{-2} day^{-1}) also play important role towards yield. Similar findings were obtained by Nand (2015), who reported higher nutrition at higher fertilizer levels resulted in better growth of plant in terms plant height and dry weight. Increased leaf area index (LAI) at different growth stages was due to higher leaf area under the higher fertility levels (200 and 150 % RDF) which made the crop photosynthetically more active and similar results were reported by Reddi and Reddy (2007). Increased growth and yield parameters in 200 % RDF were also due to higher higher available nutrients and their uptake. These results are conformity with the findings of Sreelatha *et al.* (2012). They reported higher yield and it's parameters in higher fertilizer levels (300:105:105 kg N-P_2O_5-K_2O ha^{-1}) as plant could express its full genetic potential in higher fertility levels and better fertilizer levels reduced the barrenness percent. Revathi *et al.* (2017) also found similar results and which was due to higher supply of nitrogen which increased the growth and also photosynthetic area, thus resulting in higher dry matter accumulation. Higher dose of N along with zinc decreases the barren plants. Sapkota *et al.* (2017) reported that nitrogen involved in cell division and elongation resulting increased growth parameters due to higher N application. The results are also in conformity with the findings of Damor *et al*. (2017) who reported higher yield and yield attributes of *winter* maize due to application of higher dose of inorganic fertilizer. There was a movement of photosynthates from source to sink and better physiological process. Nand (2015) showed that higher yield and its attributes were obtained at higher fertility levels which are due to adequate supply of nutrients in improving the overall growth of the plant which directly increase the yield and there was better movement of photosynthates from source to sink and better physiological processes at higher fertilizer level. The results are also in close agreement with the findings of Mathukia *et al.* (2014) who reported higher growth and yield attributes at higher nitrogen and phosphorus levels which was due to congenial nutritional environment for plant system on account of their greater availability from soil, which resulted in greater synthesis of amino acids, proteins and growth promoting substance, which enhanced the meristematic activity and increased the cell division and cell elongation. Further application of higher dose of fertilizer have increased interception, absorption and utilization of radiant energy which in turn increased photosynthesis and thereby plant height, stem girth and finally dry matter accumulation. Sindhi *et al.* (2016) also found similar findings and reported higher yield was obtained with application 100 % RDF compared to 75 and 50 % RDF which was due to increased absorption of nutrients and their assimilation, supply of nutrients in balanced quantity enabled the plants to assimilate sufficient photosynthetic products and thus increased the dry matter accumulation. The increased grain and straw yield can also be ascribed to the effect of adequate availability of NPK in soil, may cause increase in root growth, thereby increasing nutrient uptake. Rehman *et al.* (2016) reported higher grain yield and its attributes of *winter* maize which was achieved at higher nitrogen level due to proper translocation of sugar and starch in the grain and more synchronous flowers.

Interaction effect of sowing windows and fertility levels on *winter* maize

Interaction effect of sowing windows and fertility levels showed significant effect. Sowing during 1st week of October along with application of 200 % RDF (W_1F_3) recorded significantly higher grain and stover yield (91.42 q ha^{-1} and 130.5 q ha^{-1}, respectively) and it was on par with sowing during 2nd week of October along with application of 200 % RDF (W_2F_3) and sowing during 1st week of October along with application of 150 % RDF (W_1F_2). The increased grain yield and stover yield was due to improved yield attributes *viz.,* length of cob (17.4 cm), girth of cob (17.6 cm), number of grain rows per cob (17.3) and test weight (36.23 g). (Table 2). Increase in yield and yield attributes was due higher growth in terms of plant height (234.6 cm), leaf area (45.97 dm^2 plant^{-1}) and leaf area index (3.83) and total dry matter production (291.19 g plant^{-1}) (Table 1 and Fig. 1c) which increased AGR (1.86 g day^{-1}) and CGR (15.59 g m^{-2} day^{-1}) (Table 1). These results are similar with findings of Verma *et al.* (2012) and he reported early planting and higher fertilizer levels favours good plant height, leaf area index and dry weight per plant due to favourable climatic conditions especially temperature which increased metabolic activities, increased assimilation and cell division within the plant. Increased growth attributes at W_1F_3 was due to higher accumulation of GDD, PTU and HTU. Further increased uptake of nutrients and available soil nutrients increased grain yield crop sown during 1st week of October along with application of 200 % RDF (W_1F_3) compared to other treatment combinations. These results are conformity with the findings of Damor *et al.* (2017). They reported early planting and higher fertility levels recorded higher grain and stover yield. Similar results were obtained by Hugar (2015) and who reported higher GDD accumulation in early planting. Increased yield with increased fertility levels was due to more assimilation rate which increased growth characters and reproductive structures. The increased application of nutrients increases the uptake of nutrients by plants in *winter* maize which might be due congenial nutrient environment in soil and availability higher nutrients in rhizospere. The similar findings were recorded by Jaswinder *et al.* (2019).

Conclusion

Based on the results it was concluded that planting of winter maize hybrid during second week of October with application of FYM @ 10 t/ha and nutrients @ 150 % RDF along with $FeSO_4$ and $ZnSO_4$ each @ of 25 kg ha^{-1} found optimum for realising higher maize grain yield, higher gross returns and net returns as compared to application of nutrients @ RDF (150 kg N ha^{-1}, 65 kg P_2O_5 ha^{-1} and 65 kg K_2O ha^{-1}) and at higher application of nutrients @ 200 % RDF.

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