"EFFECT OF GROWTH REGULATORS ON SEED FILLING IN SUNFLOWER DURING KHARIF SEASON"

By

Mr. Kengare Rahul Ankush

(Reg. No. R/016/067)

DEPARTMENT OF AGRICULTURAL BOTANY

POST GRADUATE INSTITUTE

MAHATMA PHULE KRISHI VIDYAPEETH,

RAHURI – 413 722, DIST - AHMEDNAGAR,

MAHARASHTRA STATE (INDIA)

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In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL BOTANY (PLANT PHYSIOLOGY)

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2018

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or institute
for a Degree or
Diploma.

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The assistance and help received during the course of this investigation have been duly acknowledged.

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Date: / / 2018

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Place: M.P.K.V., Rahuri *(Rahul A. Kengare)*

Date: / /2018

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
@	At the rate of
°C	Degree Celsius
µM	micro molar
2,4-D	2,4-Dichlorophenoxyacetic acid
Anon	Anonymous
B	Boron
BA	6-benzyladenine
BAP	6-Benzylaminopurine
C.D.	Critical difference
CKs	Cytokinins
Cm	Centimeter
DAS	Days after sowing
dm^2	Decimetre square
et al.,	et alia, and other
etc.	Etcentra (and other)
Fig.	Figure
G	Gram
$g\ kg^{-1}$	Gram per kilogram
GA_3	Gibberellic acid
Ha	Hectare
HI	Harvest Index
IBA	Indole-3-butyric acid
i.e.	id est, that is
Kg	Kilogram
kg/ha or $kg\ ha^{-1}$	Kilogram per hectare
L	Liter (s)
Mg	Milligram (s)
$mg\ L^{-1}$ or mg/l	Milligram per litre
Ml	Millilitre
mM	Milli molar

Mm	Millimetre
M.P.K.V.	Mahatma Phule Krishi Vidyapeeth
MS	Murashige and Skoog
N	Nitrogen
N.S.	Non significant
NAA	Naphthalene acetic acid
P	Phosphorous
PGRs	Plant growth regulators
Plant $^{-1}$	Per plant
Ppm	Parts per million
Q	Quintals
q ha^{-1}	Quintal per hectare
RDF	Recommended dose of fertilizer
S.E.	Standard error of mean
TIBA	2,3,5-Tri-iodobenzoic Acid

ABSTRACT

"EFFECT OF GROWTH REGULATORS ON SEED FILLING OF SUNFLOWER DURING KHARIF SEASON"

By

Mr. KENGARE RAHUL ANKUSH
A candidate for the degree
of
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2018

Research Guide	:	Dr. S. K. Ransing
Department	:	Agricultural Botany
Major Field	:	Plant Physiology

A field experiment was conducted during *Kharif*, 2017 at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar to study the "effect of growth regulators on seed filling of sunflower during kharif season".

The experiment was laid out in a randomised block design (RBD) with three replications and eight treatments involving variety Phule Bhaskar and the plant growth regulators *viz.*, T_1 [Control], T_2 [GA_3 (250 ppm)], T_3 [TIBA (240 ppm)], T_4 [NAA (50 ppm)], T_5 [Kinetin (200 ppm)], T_6 [BA (250 ppm)], T_7 [Boron (0.2%)], T_8 [Hand Pollination].

The present study was conceptualized and executed to find out an appropriate growth regulator for seed filling in sunflower (*Helianthus annuus* L.). The foliar sprays of PGR's were given two times at the stage of (a) 50% flowering (b) seed formation.

Among all the treatments, treatment T_7 (0.2% boron) flowered earlier (62 days) and took minimum number of days (88.67 days) to maturity as compared to other treatments.

In case of yield and yield contributing characters *viz.*, head diameter, total number of seeds/head, total number of filled seeds/head, total number of unfilled seeds/head, seed filling percentage, weight of seeds per head, total dry weight of the plant, yield kg/plot, yield q/ha, oil content, among all the treatments, treatment T_7 (0.2% boron) resulted best performance which was significantly superior over control. The treatment T_3 (TIBA 240 ppm) recorded highest 100 seed weight (8.69 g) followed by treatment T_7 (0.2% boron) showed best performance.

Among all the treatments, the treatment T_7 (0.2% boron) showed best result and superior over all treatments when applied at the stage of initiation of flowering and seed formation.

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1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the most important oilseed crops of the world because of the adequate concentration of unsaturated fatty acids (900 g kg^{-1}) in its oil has gained popularity among all the oilseed crops. The excellent quality of sunflower oil is due to its richness with high degree polyunsaturated fatty acids, anti-cholesterol properties, short duration, wide adaptability to soil and climatic conditions, photo and thermo-insensitiveness, drought tolerance and higher oil yield per unit area. In India, it is cultivated over an area of about 2.4 million hectares with the production of 1.44 million tonnes with productivity of 6.08 q ha^{-1} as against 12.71 q ha^{-1} of the world productivity (Rasool *et al*., 2013).

Helianthus annuus, the common sunflower, genus *Helianthus* and family Compositae, is a large annual forb which grown as a crop for its edible oil. In India, important sunflower growing states are Karnataka, Andhra Pradesh, Maharashtra, Bihar, Orissa, Tamil Nadu etc.

Sunflower is an important oilseed crop with almost 20-27% protein and 40-47% oil content. It is a wealthy source of vitamins A and D. Its oil is called premium oil due to the presence of oleic acid (16.2%) and linoleic acid (72.5%) with high percentage (60%) polyunsaturated fatty acid. The seed cake of sunflower used for cattle feed which is a good source of protein (Tahir *et al.*, 2014).

The fruit (grain) of the sunflower is formed by the pericarp (hull), which comprises between 20 and 25% of the fruit weight, and the kernel or seed (mostly embryo) where the largest proportion of lipids and dry matter is stored.

Seed setting and filling is one of the most important constraints in sunflower production and often considered to be a major reason for low productivity. Besides poor agronomic management, there are several genetic, physiological and environmental factors causing poor seed setting and filling in sunflower. The sporophytic type of self-incompatibility mechanism is one of the genetic reasons for poor seed setting in sunflower. The physiological mechanisms that regulate seed setting and filling in sunflower are complex (Ram and Davari, 2011).

Poor seed setting and seed filling are the serious problems in sunflower cultivation. These are attributed to many factors. Sunflower, being protandrous and self-incompatible, is almost dependent on insects for pollination and wind pollination in it is negligible. However, only honey bees are not sufficient to cause maximum seed yield and quality. This has to be supplemented with hand pollination and plant growth regulators.

Plant growth regulators (PGRs) have the capacity to modify every phase of plant growth spanning from seed germination to crop maturity. Since most plant growth and seed development processes are regulated by natural plant hormones, many of these processes might be manipulated either by altering the endogenous hormone level or by changing the capacity of the plant to respond to its natural hormones. It is well known that plant hormones are involved in grain filling and seed development (Al- Jobori, 2012).

In Maharashtra, sunflower crop cultivated mainly in rabi and summer season. There is potential for further increasing area under sunflower cultivations. Under normal conditions sunflower gives good performance. However, there is problem of poor seed setting and filling. There are many reasons such as self-incompatibility, inadequate water supply, insufficient nutrient supply and lack of pollination. Applying growth regulators like GA_3, TIBA, NAA, Kinetin, BA, Boron and hand pollination possibly can overcome the constraints and increase the productivity.

In view of this, the present investigation entitled “Effect of growth regulators on seed filling of sunflower during kharif season” is undertaken to know the response of sunflower to application of growth regulators viz., GA_3, TIBA, NAA, Kinetin, BA, Boron and hand pollination in relation to seed filling, growth and yield attributes.

Keeping these aspects in view, the present investigation was carried out with following objectives.

1. To find out an appropriate growth regulator for seed filling in sunflower (*Helianthus annuus* L.)

2. REVIEW OF LITERATURE

The literature related to present investigation entitled "Effect of growth regulators on seed filling of sunflower during kharif season" has been reviewed in this chapter.

2.1 Effect of Growth Regulators on Phenology of Sunflower

Khanna (1971), Seetharam (1976) and Sindagi **(**1977) observed from his study that the two adjacent plants in sunflower show distinct difference in percent seed set. This may be due to genetic factors such as self incompatibility or self sterility or both.

Leoplopez (1972) observed the non viability of pollen grains when anthesis phase of sunflower coincided with hot weather and scorching sun.

Chidananda (1974) reported that more number of plants per unit area or closer spacing reduces seed number, seed size, seed weight and diameter of capitulum. Less number of plants per unit area by giving wider row and plant spacing resulted in more number of well filled and bolder seeds per capitulum.

Udaykumar *et al*., (1976) found that for translocation of photosynthates from source to sink, growth hormones are essential as indicated by more translocation of metabolites when growth regulators were applied to sunflower.

The degree of chaffyness or achene sterility in sunflower capitulum, to some extent, is controlled by time of sowing and season of growth in different locations.

Singh (1977) also reported that moisture stress at flowering and seed formation stages adversely affected the seed setting.

Kannababu *et al*., (1993) observed that an increase in plant population from 55,555 to 1, 66,666 per hectare decreased the seed size and seed recovery percentage.

Sinha and Atwal (2000) suggested that there was gradual increase in seed yield from December to February registering 25 percent increase in yield over December sown hybrids. Influence of abiotic factors especially air temperature, relative humidity, day length and sunshine play vital role in stigma receptivity, pollen viability, pollinators' behaviour, fertilization and seed development behaviour.

Ram and Davari (2011) reported that self-incompatibility is the inability of fully functional pollen grains to fertilize and seed set on self pollination. Self-incompatibility of sporophytic nature is reported in sunflower that is major cause for poor seed setting in the crop.

Krudnak *et al*., (2013) concluded that B application at planting date could increase pollen viability and percent seed set of sunflower. However, the application at high rate (more than 11.3 kg B ha^{-1}) resulted in no further benefit, but tended to decrease B uptake, pollen viability and seed set. From the result of the regression analysis, it could be concluded that, in this area, the optimum levels of B application for sunflower variety “Pacific 77” is 5.6 to 11.3 kg B ha^{-1}, while for variety “S473” is 5.7 to 10.4 kg B ha^{-1}.

Buriro *et al*., (2015) concluded that the sunflower is sensitive to both excessive and deficit water which leads to decrease yield. Sunflower irrigated five (30, 45, 60, 75 and 90 DAS) and four times (30, 45, 60 and 75 DAS) resulted maximum values for growth and yield components and took more days to maturity. However, highest water stress to sunflower (two irrigations (30 and 45 DAS)) reduced sunflower days to flowering and maturity, plant height, stem girth, head diameter, seeds $head^{-1}$, seed index and seed yield. It was therefore, concluded that four irrigations (30, 45, 60 and 75 DAS) was an optimum irrigation regime for achieving higher economical sunflower seed yield.

2.2 Effect of Growth Regulators on Seed Setting, Seed Yield and Yield and Yield Attributing Characters of Sunflower

Seetharam (1976) reported that problem of poor seed setting in sunflower is mostly confined to tropical and sub-tropical countries and is not that much serious in temperate countries. This might be due to differences in temperature and other environmental factors and as well as bee number and their activity.

Udaykumar *et al*., (1976) reported that there was no later flow of photosynthates in sunflower and the leaves on one side of stem are directly connected with a particular part in the capitulum. Further, seeds which are in advance stage of development are situated in the outer zone of capitulum accumulate more quality of metabolites as compared to the seeds situated in inner zone of capitulum. So, improper translocation of metabolites from source to sink results in poor seed filling, lower specific seed weight and yield.

Singh (1977) observed that the wide variability in seed setting and number of filled seeds per capitulum among several varieties tested. He also reported that application of higher doses of nitrogen and phosphorus markedly reduced the nitrogen as top dress at budding and flowering stages and increases number of filled seeds per capitulum. Results from the coordination trials on sunflower at Bangalore also revealed that application of boron, calcium, magnesium and sulphur plays a vital role in seed setting, yield and yield components (Anon, 1976 and Anon, 1978).

Moisture stress affects photosynthesis and translocation of metabolites from source to sink and leads to occurrence of more number of unfilled seeds in sunflower capitulum.

Anon (1991) reported that varieties differ in their productivity, percent seed setting and seed filling.

Beltrano *et al*., (1994) observed that foliar spray of gibberellic acid (GA) and benzyladenine (BA) for enhancing vascular connections between the outer and inner parts of the capitulum and to increase grain yield by reductions in the percentage of empty achenes in the inner portion of the capitulum. They reported that BA 150 mg/l + GA 150 mg/l applied at 40 days after emergence significantly reduced the percentage of empty achenes and increased achene weight.

Hernández (1996) reported that GA_3 treatment did not produce significant changes in inflorescence growth except that there was an increase in the rate of floral development. The final stage of inflorescence formation (FS 10) was then obtained 9 days earlier than in the control.

Ganapati *et al*., (1997) reported that when sink number increased, the photosynthates distributed equally and as a consequence the seed weight might have been decreased.

Vasudevan *et al*., (2002) reported that the spraying of TIBA along with NAA had highest head diameter (19.2 cm), number of filled seeds (10.6% increase over control), seed filling percentage (85.2%), seed yield (29.6 q/ha), test weight (63.3 g) and volume weight (4.9 g higher than control). Among genotypes KBSH-1 produced maximum yield and yield components. Yield parameters like test weight and seed density were differed significantly due to interaction of both growth regulators and genotypes.

Alkio *et al*., (2003) reported that both seed set and seed filling in sunflower depend on the source–sink ratio. The effect of source–sink ratio on seed set was always strongest in the centre, whereas peripheral whorls were not affected. Achene mass was affected in all parts of the capitulum. Therefore, it is concluded that source limitation is a major cause for empty achenes in sunflower plants grown under non-stress conditions.

Musalma Bibi *et al*., (2003) reported that the three concentrations of GA_3 i.e. 10, 20 and 30 mg L^{-1} were sprayed 30 days after germination. Increasing concentrations of GA_3 gradually improved oil and carbohydrate contents. Yield parameters i.e. achene yield, 1000-achene weight, capitulum diameter and dry biomass also, gradually increased as the concentration of GA_3 increased.

Reddy *et al*., (2003) reported that application of TIBA alone or TIBA with NAA increased seed yield by 29 and 34% respectively.

Reddy *et al*., (2003) reported that the soil application of boron (2 kg/ha) at ray floret stage increased the HI to an extent of 29% and the seed yield by 53%. Boron is known to play an important role in translocation of sugars.

Oyinlola (2007) studied on the three different cultivars of sunflower in response to boron fertilizer. Their result showed that the variety recorded the highest plant height at 8 kg B per ha while Funtua have the highest seed yield at 4 kg B per ha. The highest percentage oil content was recorded by Isaanka variety. Toxicity symptoms and reduction in yield were observed at the highest level B (12 kg B per ha) in all the varieties. Percentage oil content correlated with capitulum diameter and seed yield. Regression analysis also revealed that the optimum B rate for the three cultivars and four years of trial for the various parameters determined ranged from 5.60-8.40 kg B per ha.

Somroo *et al.,* (2007) observed that as the boron levels increased, all the sunflower parameters also increased. The taller plants (255.33 cm), more stem girth (10.00 cm), expended heads diameter (27.16 cm), more number of seeds per head (1513.33), heavy seed weight per head (103.33), high seed index (90.00 g) and maximum seed yield (2355.00 kg per ha) were noted with the application of 2.5 kg B per ha followed by 2.0 kg B per ha both applied as foliar spray with combination of recommended NP doses. The minimum values of all crop parameters were observed in the plots where no fertilizer was applied. They were concluded that foliar application of boron at 2.0 to 2.5 kg per ha with recommended NP levels increased all the crop parameters including yield, hence these levels should be applied for satisfactory sunflower growth and yield.

Al-Amery *et al*., (2011) showed that boron and green Leaf area/LAI measured at the end of seed filling were linearly related in the spring crop. In the autumn crop, the relationship between boron and dry matter yield was linear, and applications above 100 mg L^{-1} significantly increased dry matter compared to the control. For the autumn crop, 100, 200, and 250 mg L^{-1} significantly increased seed number compared to the control, but only the 150 mg L^{-1} treatment increased seed weight significantly. Boron tended to decrease the empty seed percentage and for the spring crop, this was incremental and linear with applications above 150 mg L^{-1} leading to significant reductions in empty seed percentage. Seed yield increased linearly in the autumn crop in response to boron, and 200 and 250 mg L^{-1} applications gave significant increases in yield compared to the control.

Ram and Davari (2011) reported that application of TIBA to head has resulted in increased filling and test weight by way of increased translocation of photosynthates to sink. Hence, use of growth regulator like TIBA would be beneficial.

Ram and Davari (2011) reported that the Sunflower responds profitably to the use of secondary nutrients and micronutrient viz., boron. Boron application at ray floret opening stage improved seed set and filling percentage. Hence, application of boron at this stage is suggested.

Al-Jobori (2012) found that GA, Kinetin or mixture of both increased the percentage of filled seeds relative to the untreated plants. Higher increments were obtained by applying Kinetin or mixture of both GA and Kinetin. It was revealed that the role for GAs lies mainly in the seed filling, whereas CKs are most important in seed set and increase sink strength, thereby decrease the rates of abortion.

Khan *et al*., (2015) concluded that the higher head diameter (18.30 cm), number of achene per head (1266.44), 1000-achene weight (43.17 g) achene yield (2039.33 kg ha^{-1}), biological yield (9223.11 kg ha^{-1}) and harvest index (22.10%) were registered when boron was foliar applied @ 200 mg L^{-1} at ray floret stage. Among sunflower hybrids, Patron 551 produced significantly higher growth and yield attributes as compared with Patron 851 and S-278 hybrids. Their study suggested that the selection of Patron 551 hybrid with practicing boron foliar application @ 200 mg L^{-1} at ray floret stage could be helpful in achieving the sunflower crop genetic potential.

Nagarathna *et al*., (2016) reported that Manipulation of sink capacity by spraying 240 ppm TIBA with 120 ppm NAA and 0.2% boron improved the rate of translocation which in turn increased the productivity by 33% to 36%. Due to more biomass and yield, harvest index was also increased by 32%.

Nagarathna *et al*., (2016) concluded that the cycocel (3000 ppm) at ray floret stage increased the seed yield followed by spraying of 150 ppm BA at ray floret stage. These hormones play a major role in increasing translocation of photosynthates from source to sink especially during seed filling period. Further, increase in source size by applying 200% nitrogen combined with growth regulator mixture by maintaining recommended plant density, productivity can be increased up to 10-15%.

Ozgul Gormus and Celaleddin Barutcular (2016) concluded from his study that all levels of boron produced higher head diameters over control only one out of four sites. Boron applied at the level of 3 kg ha^{-1} produced the highest 1000 seed weight of 47.5 g representing an 18% increase over the control. Boron applied at the level of 1 kg ha^{-1} produced the highest seed yield, representing a 25% increase over the control only at one out of four sites.

Prathima *et al*., (2017) investigated the influence of boron application on growth and growth attributes of sunflower using randomized complete block design with 3 replications and 11 treatments comprising control, seed treatment at 2, 4, 6 g of borax kg^{-1} of seed, soil application of borax @ 11 kg ha^{-1}, foliar application of borax at ray floret opening stage @ 0.2%, 0.4% and 0.6 % and dusting of borax at ray floret opening stage at 2 kg ha^{-1}, 3 kg ha^{-1} and 4 kg ha^{-1}. Study revealed that both at 30 and 60 DAS significantly higher plant height (19.73 cm and 146.4 cm respectively), number of leaves (10.6 and 24.73 respectively), leaf area (998.3 cm^2 $plant^{-1}$ and 4296 cm^2 $plant^{-1}$ respectively), root dry matter (2.30 g $plant^{-1}$ and 9.07 g $plant^{-1}$ respectively), shoot mater production (6.97 g $plant^{-1}$ and 8.07 g $plant^{-1}$ respectively), total dry matter (9.27 g and 87.13 g respectively), higher root to shoot ratio (0.43 and 0.13 respectively).

Kawade *et al.*, (2018) reported that the maximum leaf area plant^{-1} (76.97 dm^2), stem girth (8.09 cm), head diameter plant^{-1} (18.83 cm), seed yield (1644 kg ha^{-1}), oil yield (575 kg ha^{-1}) and protein yield (312 kg ha^{-1}) with RDF + Borax @ 5.0 kg ha^{-1}.

2.3 Effect of Hand Pollination on the Seed Setting, Seed Yield and Yield Attributing Characters of Sunflower

Radoev (1954) reported that hand pollination of florets which were newly opened, 3 to 4 days old and two weeks old florets resulted in seed set of 87, 69 and 21 percent, respectively. Thus, when hand pollination is done the reflexed stigmatic lobes might pick up the pollen but usually remain ineffective because of non receptive stigma.

Shinde and Dhoble (1979) reported that by hand pollination supplemented with insect pollination filled seeds percentage increased from 79 to 84%.

Subbaiah (1983), Anon (1984) and Gowda (1984) reported that hand pollination, during flowering, in the morning hours increased the percent seed set and yield.

Singh and Yadav (1985) found that hand pollination resulted in higher achene yield and percentage achene setting than those obtained with open pollination. Average achene yield for overall varieties with hand pollination was 59.3 and 23.9 percent more than open pollinated achene yield in rainy and winter seasons, respectively.

Merwade *et al*., (1993) reported that supplementary hand pollination has significantly recorded higher percentage of filled achenes, achene weight, oil content and germination capacity when compared to open pollination. They also reported that both *Kharif* and *Rabi* seasons exhibited marked and consistent variation in the pattern of achene set and filling in a capitulum irrespective of sowing years and pollination methods.

Merwade *et al*., (1994) also reported that marked and consistent variations in the pattern of achene set and its quality attributes in both *Kharif* and *Rabi* seasons for three years, irrespective of pollination methods. On an average, it recorded significantly higher filled achene percentage, filled achene weight and oil content per capitulum in *Rabi* season than *Kharif* season.

Yadava *et al*., (1994) reported that pollination efficiency in terms of seed set percent, number of seeds/head, seed size and 1000 seed weight and seed yield was satisfactory and better during spring than autumn planting because of favourable weather conditions. He also reported that supplementary hand pollination increased the seed set percent in both planting seasons.

Ram and Davari (2011) reported that by providing supplemental pollination, either by hand pollination or through increasing pollinators (bees) activity has increased the seed set and filling percent in sunflower.

3. MATERIALS AND METHODS

The experimental material used and the methods followed during the course of present investigation are briefly described in this chapter.

3.1 Location of the Experimental Site

The present investigation entitled “Effect of growth regulators on seed filling of sunflower during kharif season” was conducted during kharif 2017 at PGI Farm, Department of Agricultural Botany, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri.

3.2 Experimental Details

3.3.1 Design and Layout

The experiment was laid out in randomized block design and replicated thrice with eight treatments and the layout of which is illustrated in Fig. 1.

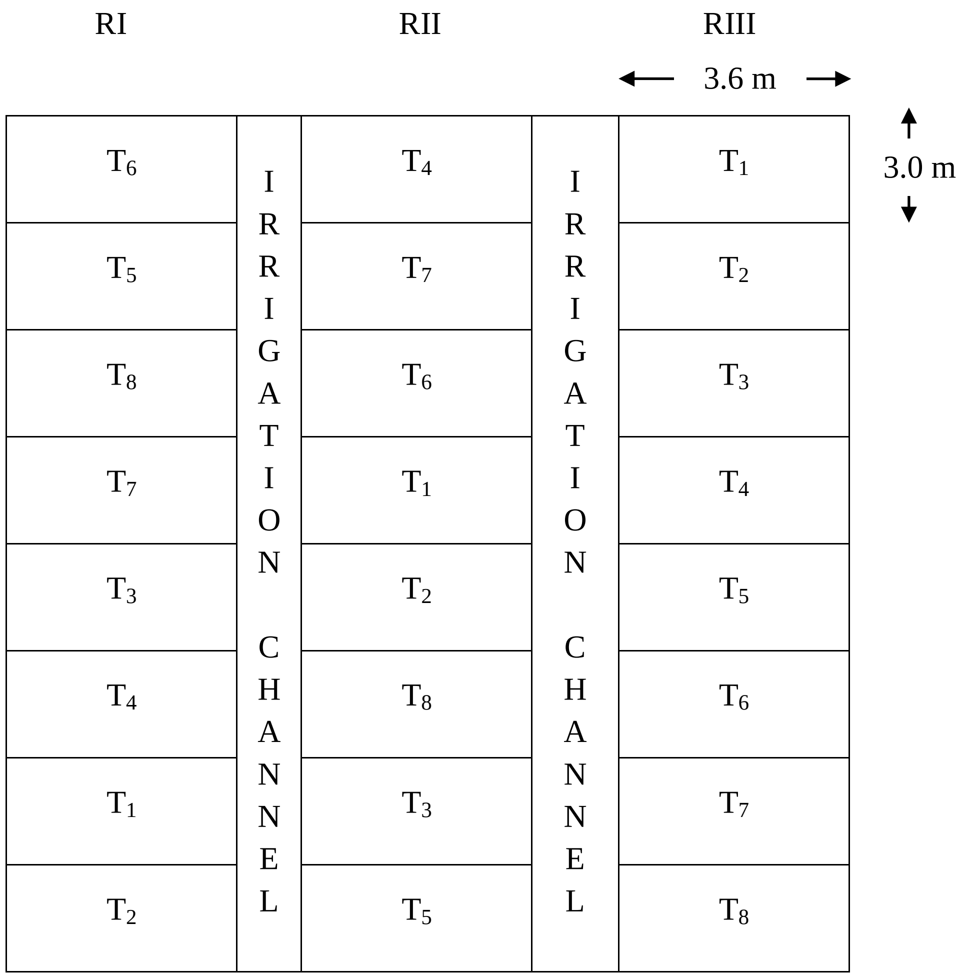

Fig. 1: Layout plan of the experiment

Design : RBD	Gross Plot size: 3.6 x 3.0 m	Variety: Phule Bhaskar
Replications: Three	Net Plot size : 2.4 x 2.4 m	Spacing: 60 x 30 cm

3.3.2 Treatment Details

1) T_1 - Control
2) T_2 - GA_3 (250 ppm)
3) T_3 - TIBA (240 ppm)
4) T_4 - NAA (50 ppm)
5) T_5 - Kinetin (200 ppm)
6) T_6 - BA (250 ppm)
7) T_7 - Boron (0.2%)
8) T_8 - Hand Pollination

3.3.3 Plot Size

Gross: 3.6 x 3.0 m

Net: 2.4 x 2.4 m

3.3.4 **Spacing:** 60 cm x 30 cm

3.3 Cultivation Details

3.3.1 Preparatory Cultivation

The experimental field was prepared with a tractor drawn cultivator followed by blade harrow. The soil was smoothened with rotavator to break down the clods and to prepare a fine seed bed. The land was made into plots of required size and laid as per the plan and levelled within each plot. The plots were laid out as per the layout plan.

3.3.2 Seeds and Sowing

Sunflower seeds of variety Phule Bhaskar were collected from ZARS, Solapur and used for sowing. A pre-sowing irrigation was given and sowing was taken up at optimum soil moisture content. Two seeds were hand dibbled at each hill with a spacing of 60 x 30 cm.

3.3.3 Fertilizers

Recommended dose of 40:30:30 kg N, P_2O_5, K_2O per ha in the form of Urea, DAP and muriate of potash was applied to the soil as basal dose.

3.3.4 After Care

Gap filling was done within 11 DAS and thinning was carried out after full emergence of seedlings and maintained only one healthy seedling at 22 DAS. Two hand weeding were done at 20 and 40 days after sowing.

3.3.5 Plant Protection

For pest and disease control two sprays of Quinalphos 25% EC @ 2 ml per litre of water was sprayed to control sucking pests and leaf eating caterpillar. Bavistin @ 2 g $litre^{-1}$ of water at 40 DAS was done as a prophylactic measure against leaf eating caterpillar, green leaf hopper and root rot disease.

3.3.6 Irrigation

One pre-sowing irrigation and subsequent irrigations were given as and when necessary.

3.3.7 Harvesting

The crop was harvested at physiological maturity based on visual observation. The crop was considered mature, when the back of heads turned to lemon yellow. The heads of border rows were harvested first and treated as bulk. Later the heads of crop from net plot was harvested.

3.3.8 Threshing

The heads were sun dried, shelled with hand and the seeds were separated. Later seeds were sun dried, cleaned and weighed separately for each plot. The Stover yield was recorded after sun drying the plant to a constant weight.

3.4 Experimental Observations of Crop

Three plants were selected randomly from net plot and tagged for recording growth and yield attributes throughout crop growth period.

3.4.1 Days Required for Bud Initiation

The number of days required for the bud initiation in 50% of the plants in each plot was recorded.

3.4.2 Days Required for 50% Flowering

The number of days required for the florets to appear in 50% of the plants in each plot was required as days to 50% flowering.

3.4.3 Days Required for Maturity

The number of days required for maturity was recorded from each plot by the indications such as drying of the leaves, yellow colour on the back side of the capitulum and hardening of seeds.

3.4.4 Head (Capitulum) Diameter (cm)

Diameter of the heads from the labelled plants were measured, average diameter was worked out and expressed in centimetres.

3.4.5 Total Number of Filled Seeds Per Head

The seeds obtained from each head of ten sampled plants from each replication were cleaned separately. The filled seeds were manually separated, counted, totalled and average was worked out.

3.4.6 Total Number of Unfilled Seeds Per Head

The seeds obtained from each head of three sampled plants per plot after threshing were cleaned and filled and unfilled seeds were separated. Unfilled seeds were counted, totalled and average was calculated.

3.4.7 Total Number of Seeds Per Head

Total seeds (filled and unfilled) obtained from each head of sampled plants from each replication were counted and expressed as total number of seeds per head.

3.4.8 Seed Filling Percentage

The percentage of filled seeds to the total seeds was worked out for each treatment using the following formula.

$$\text{Seed filling (\%)} = \frac{\text{Total number of filled seeds per head}}{\text{Total number of seeds per head}} \times 100$$

3.4.9 100 Seed Weight (g)

Hundred seeds were counted manually in all the treatments, replication wise. The weight of hundred seeds was recorded in grams.

3.4.10 Weight of Seeds Per Head (g)

From each head, seeds were separated, cleaned, weighed and expressed as seed weight per head in g per head.

3.4.11 Total Dry Weight of the Plant (g)

Three plants were uprooted from the destructive sampling area at head initiation stage and at maturity stage and were sun dried initially and subsequently dried in hot air oven at 60°C till constant weight was obtained. Their weights were recorded and expressed in g per plant.

3.4.12 Seed Yield (Kg/plot)

Seed obtained from the net plot was thoroughly sun dried, weighed and yield was expressed in kg per plot.

3.4.13 Seed Yield (q/ha)

Seed obtained from the net plot was thoroughly sun dried, weighed and yield was expressed in kg per hectare.

3.4.14 Harvest Index (%)

The relationship of economic yield (seed) to the total biological yield was estimated by using the following formula and was expressed in percentage.

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.4.15 Oil Content (%)

Oil content in the seeds of each treatment was estimated by Nuclear Magnetic Resonance (NMR) instrument and expressed in percentage.

3.5 Statistical Analysis

The data were analyzed duly following the analysis of variance technique outlined by Panse and sukhatme (1995). The statistical significance was tested with ‘F’ test at 5% level of probability and wherever the ‘F’ value was found significant, critical difference (CD) was computed to test the significance.

4. RESULTS AND DISCUSSION

Sunflower holds great promise as an oilseed crop because of its short duration, photo insensitivity and wide adaptability to different agro-climatic regions and soil types of Maharashtra. Though the crop has several advantages, some of the shortcomings are poor seed setting and large percentage of hollow seeds in its capitulum with poor germination. This problem demands greater attention due to its adverse effect on seed yield and quality of produce. Insufficient supply of macro and micro nutrients seems to be one of the major causes of poor seed yield in sunflower. Among the micronutrients, boron appeared to have a special role in reproductive phase influencing the seed setting and filling. Considering the beneficial effect of boron and other plant growth regulators on seed yield and quality of sunflower besides N, P and K, the present investigation entitled "effect of growth regulators on seed filling in sunflower during kharif season" was undertaken to determine the appropriate growth regulator and its effect on crop growth and yield when applied with recommended fertilizers. The results of the investigation are discussed in this chapter with proper reasoning and seeking support from the available literature to establish appropriate relationship of cause and effects.

4.1 Phenological Characters:

Various phenological characters like days required for bud initiation, days required for 50 per cent flowering and days required for maturity were studied (Table 1).

The results on days required for bud initiation and 50% flowering were found non-significant. However, days required for maturity was significantly influenced. The minimum days required for maturity (88.67) was observed in treatment T_7 (0.2% boron) and the maximum days required for maturity was (93.33) in treatment T_1 (control).

Table 1: Days required for bud initiation, 50% flowering and maturity in sunflower variety Phule Bhaskar as influenced by different treatments

Sr. No.	Treatments	Bud initiation	50% Flowering	Maturity
T_1	Control	39.67	64.33	93.33
T_2	GA_3 (250 ppm)	39.00	63.67	92.33
T_3	TIBA (240 ppm)	38.67	63.33	89.33
T_4	NAA (50 ppm)	38.00	64.00	92.00
T_5	Kinetin (200 ppm)	38.33	63.00	90.00
T_6	BA (250 ppm)	38.00	63.33	91.33
T_7	Boron (0.2%)	37.67	62.00	88.67
T_8	Hand Pollination	39.33	62.67	89.00
	SE($\pm$)	0.56	0.67	0.55
	CD @5%	**NS**	**NS**	1.66

4.2 Yield and Yield Contributing Characters:

4.2.1 Head Diameter (cm)

Significantly highest head diameter (17.66 cm) was observed in treatment T_7 (0.2% boron). While, the lowest head diameter (15.15 cm) was observed in treatment T_1 (control) (Table 2). Head diameter is an important yield component of sunflower. It is more or less genetically controlled character, but also influenced by the plant growth regulators and environment in which the plant is grown. The stimulatory effect of boron on sunflower plant may be due to its role in enhancing metabolic process and improving development of pollen tube. These results coincide with the finding of Reddy *et al*. (2003), Oyinlola (2007), Tahir *et al.* (2014), Khan *et al*. (2015) and Kawade *et al.* (2018).

4.2.2 Total Number of Filled Seeds/Head

The significantly highest total number of filled seeds/head (1648.67) was observed in treatment T_7 (0.2% boron) over control (1143.33).

4.2.3 Total Number of Unfilled Seeds/Head

The data with respect to number of unfilled seeds/head is presented in Table 2. The results indicated that significant difference was observed among the treatments. Number of unfilled seeds was significantly lower (184.33) in treatment T_7 (0.2% boron). However, significantly higher (307) number of unfilled seeds was observed in treatment T_1 (control). These results are similar to the findings as reported by Al-Amery *et al.* (2011).

4.2.4 Total Number of Seeds /Head

The data revealed that the highest number of seeds per head (1833.00) was observed in treatment T_7 (0.2% boron). While, the lowest number of seeds per head (1450.33) was recorded in treatment T_1 (control). For determining the yield potential of the sunflower crop, the number of seeds per head is an important yield component. Translocation of assimilates from source to sink, which ultimately increased number of seeds per head. These results are according to the findings as reported by Somroo *et al.* (2007), Reddy *et al.* (2003) and Tahir *et al*. (2014). The same findings were also reported by Khan *et al.* (2015).

4.2.5 Seed Filling Percentage (%)

Seed filling percentage is presented in Table 2. The significantly higher seed filling percentage (%) was observed in treatment T_7 (0.2% boron) (89.95%) which was significantly superior over all treatments. These results are in accordance with the findings of Krudnak *et al.* (2013).

Table 2: Head diameter, filled, unfilled, total number of seeds/head and seed filling percentage of sunflower variety Phule Bhaskar as influenced by different treatments

Sr. No.	Treatments	Head diameter (cm)	Filled seeds /head	Unfilled seeds/head	Total number of seeds/head	Seed filling percentage
T_1	Control	15.15	1143.33	307.00	1450.33	78.84
T_2	GA_3 (250 ppm)	16.96	1272.33	294.33	1566.67	81.21
T_3	TIBA (240 ppm)	17.26	1470.33	241.67	1712.00	85.93
T_4	NAA (50 ppm)	16.97	1454.67	285.67	1740.33	83.59
T_5	Kinetin (200 ppm)	17.43	1522.00	231.33	1753.33	86.81
T_6	BA (250 ppm)	16.81	1337.00	239.67	1576.67	84.80
T_7	Boron (0.2%)	17.66	1648.67	184.33	1833.00	89.95
T_8	Hand Pollination	17.51	1541.00	231.67	1772.67	86.93
	SE(±)	0.05	9.22	13.24	13.37	0.71
	CD @5%	0.16	27.95	40.15	40.54	2.15

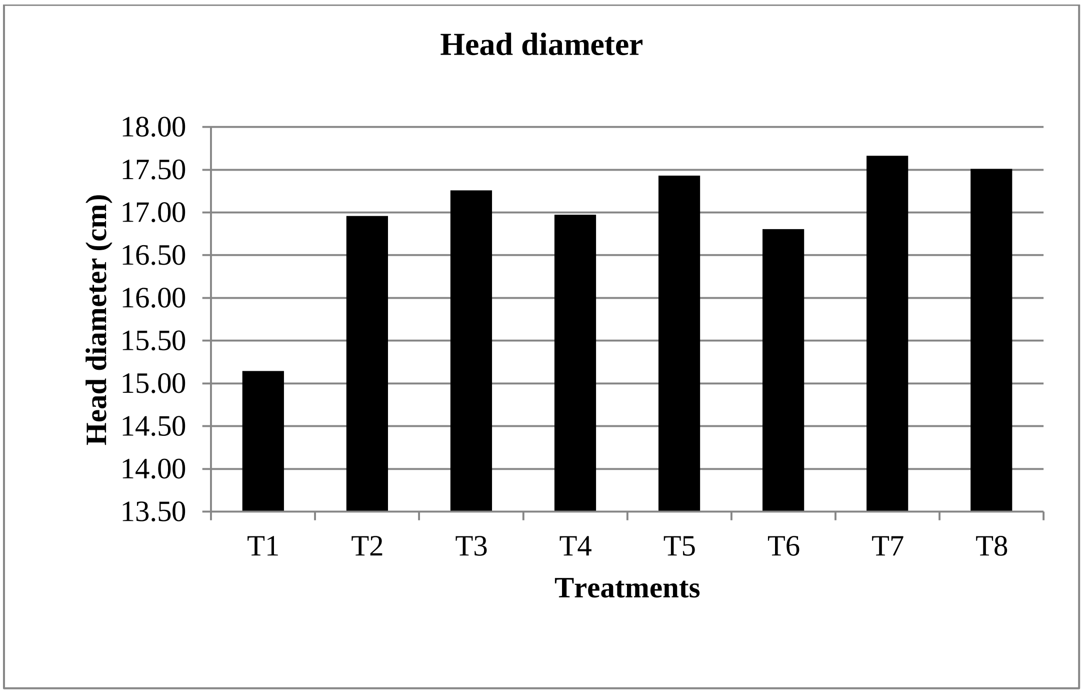

Fig. 2: Head diameter (cm) in sunflower variety Phule Bhaskar as influenced by different treatments

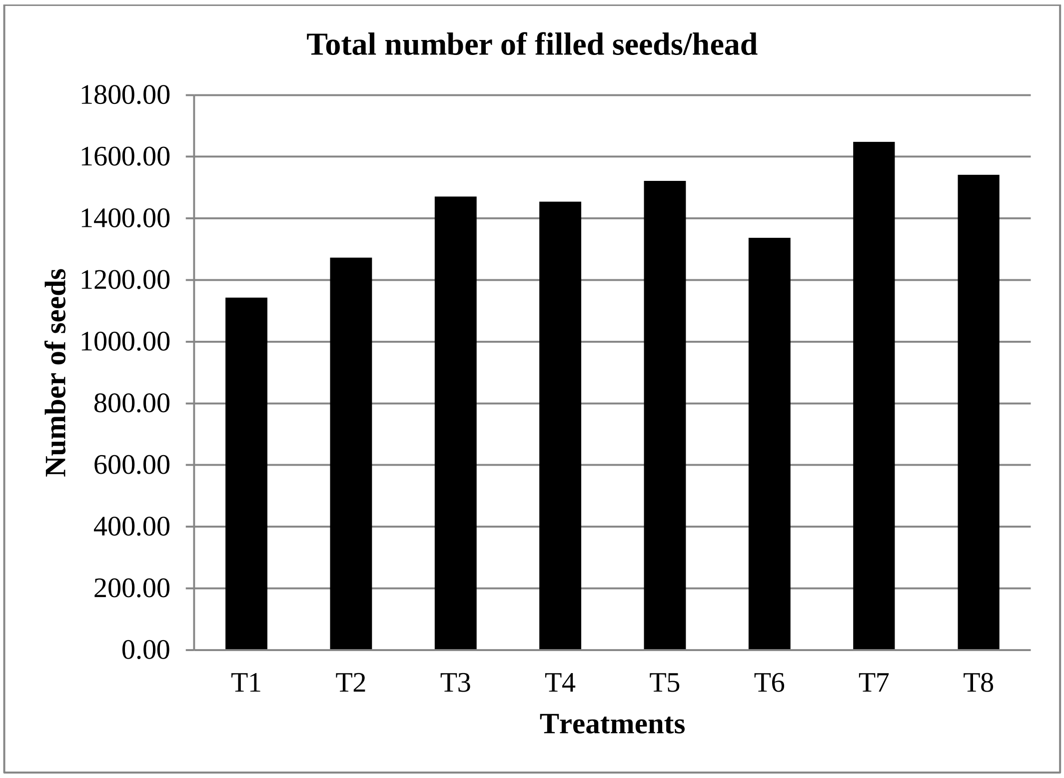

Fig. 3: Total number of filled seeds/head in sunflower variety Phule Bhaskar as influenced by different treatments

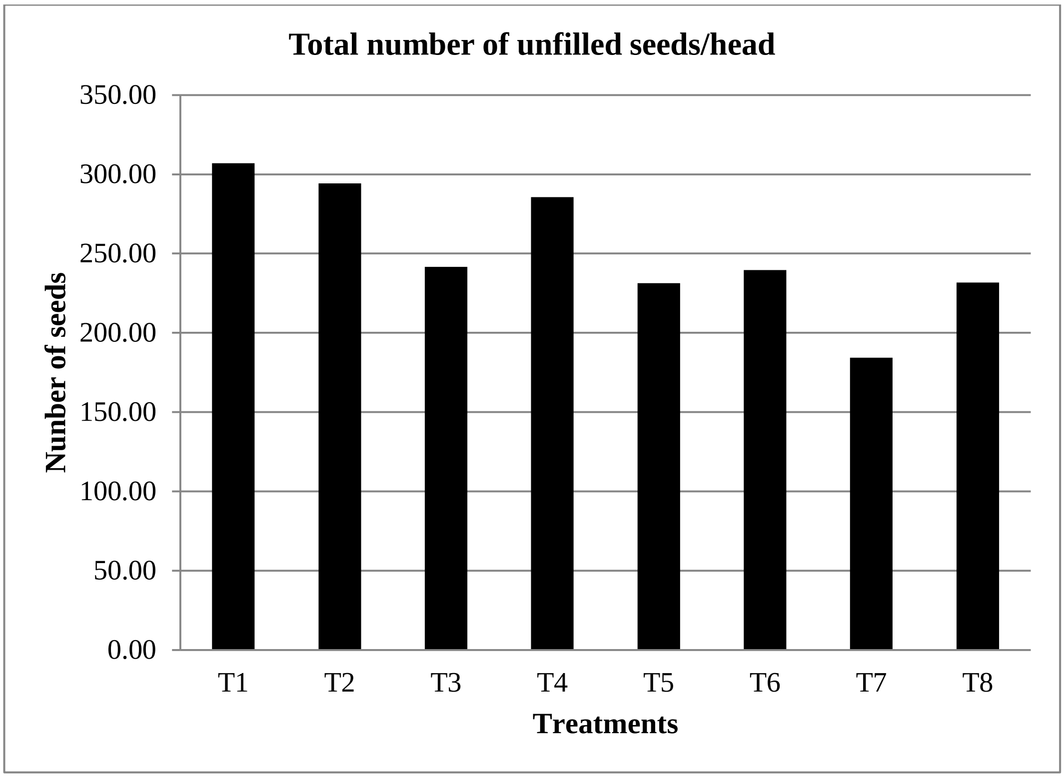

Fig. 4: Total number of unfilled seeds/head in sunflower variety Phule Bhaskar as influenced by different treatments

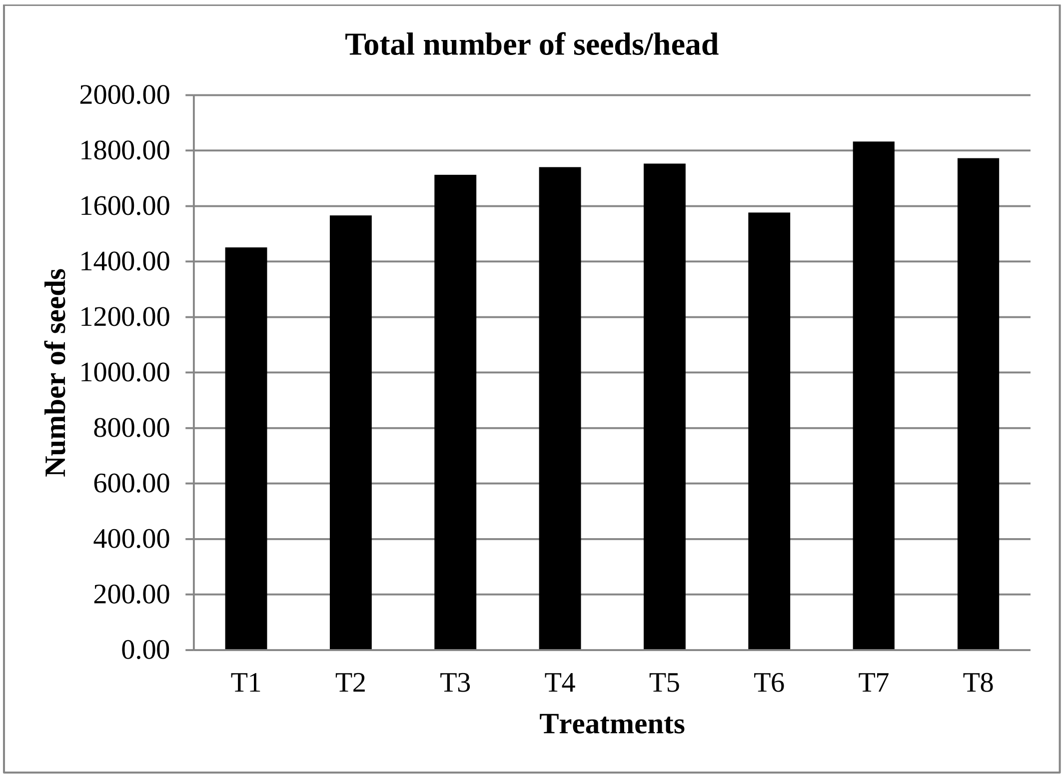

Fig. 5: Total number of seeds/head in sunflower variety Phule Bhaskar as influenced by different treatments

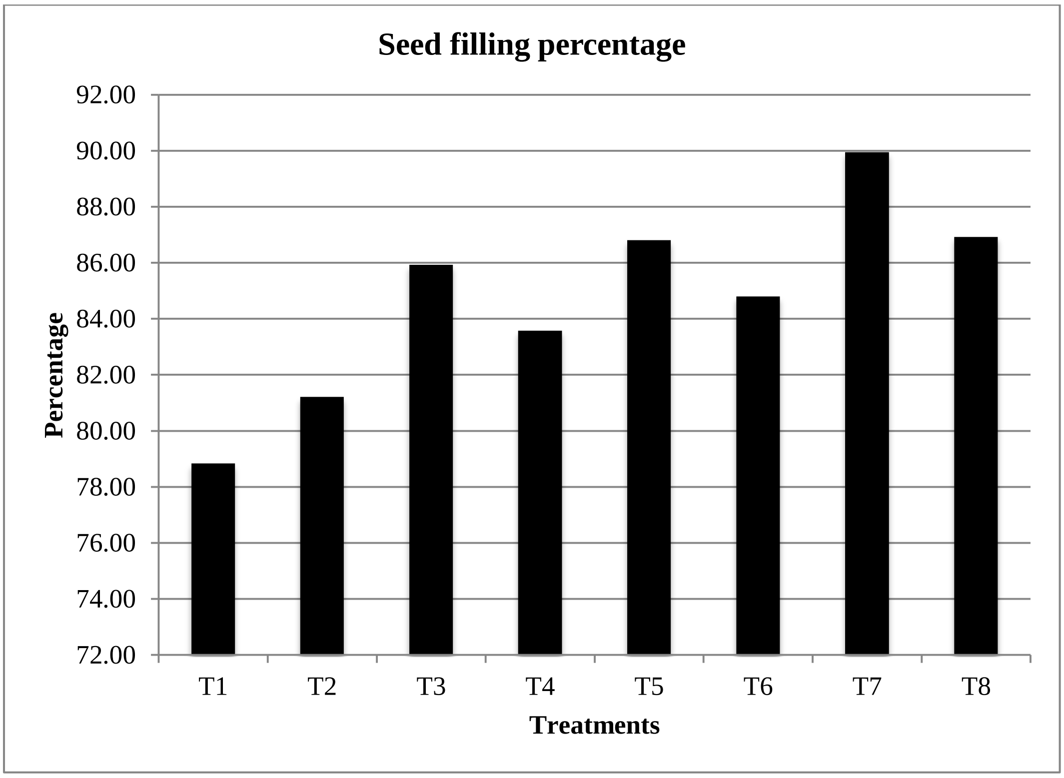

Fig. 6: Seed filling percentage (%) of sunflower variety Phule Bhaskar as influenced by different treatments

4.2.6 100 Seed Weight (g)

Significant differences observed in treatments with respect to 100 seed weight (Table 3). Significantly highest 100 seed weight (8.69 g) was recorded in treatment T_3 (TIBA 240 ppm), which was significantly superior over all treatments. It was noteworthy to point that application of TIBA to head has resulted in increased filling and test weight by way of increased translocation of photosynthates to sink. These results are in accordance with the findings of Vasudevan *et al*., (2002) and Ram and Davari (2011).

4.2.7 Weight of Seeds/Head (g)

Weight of seeds/head was influenced significantly (Table 3). Significantly highest seed weight **(**79.64 g) was recorded in treatment T_7 (0.2% boron) which was significantly superior over all treatments. These results are in accordance with the findings of Somroo *et al.* (2007) and Al-Amery *et al.* (2011).

4.2.8 Total Dry Weight of the Plant (g)

The dry matter production is the result of cumulative and complementary effect of plant height, number of leaves, leaf area and root weight. Dry matter production differed significantly due to application of boron. The significantly highest dry weight of the plant **(**176 g) was observed in treatment T_7 (0.2% boron) and the lowest (163.02 g) in treatment T_1 (control). The higher dry matter production in these treatments might be due to the boron role in increasing photosynthetic activity, which resulted in increase in plant height, number of leaves, leaf area and root growth. The same findings were also reported by Al-Amery *et al*. (2011), Ozgul Gormus and Celaleddin Barutcular (2016) and Prathima *et al*. (2017).

4.2.9 Dry Weight of Plant Excluding Dry Weight of Seeds (g)

Dry weight of plant excluding dry weight of seeds (g) was influenced significantly (Table 3). Significantly highest dry weight of plant excluding dry weight of seeds **(**96.36 g) was recorded in treatment T_7 (0.2% boron) which was significantly superior over all treatments.

Table 3: 100 seed weight (g), weight of Seeds/head, total dry weight of the plant (g) and dry weight of plant excluding dry weight of seeds (g) of sunflower variety Phule Bhaskar as influenced by different treatments

Sr. No.	Treatments	100 seed weight (g)	Weight of seeds/head (g)	Total dry weight of the plant (g)	Dry weight of plant excluding dry weight of seeds (g)
T_1	Control	6.95	68.00	163.02	95.02
T_2	GA_3 (250 ppm)	7.73	70.50	164.10	93.60
T_3	TIBA (240 ppm)	8.69	74.96	169.80	94.84
T_4	NAA (50 ppm)	7.74	74.04	168.55	94.51
T_5	Kinetin (200 ppm)	7.96	77.82	173.65	95.83
T_6	BA (250 ppm)	8.39	73.07	167.35	94.28
T_7	Boron (0.2%)	8.40	79.64	176.00	96.36
T_8	Hand Pollination	8.27	76.96	170.42	93.46
	SE($\pm$)	0.06	0.87	2.00	0.59
	CD @5%	0.19	2.63	6.07	1.80

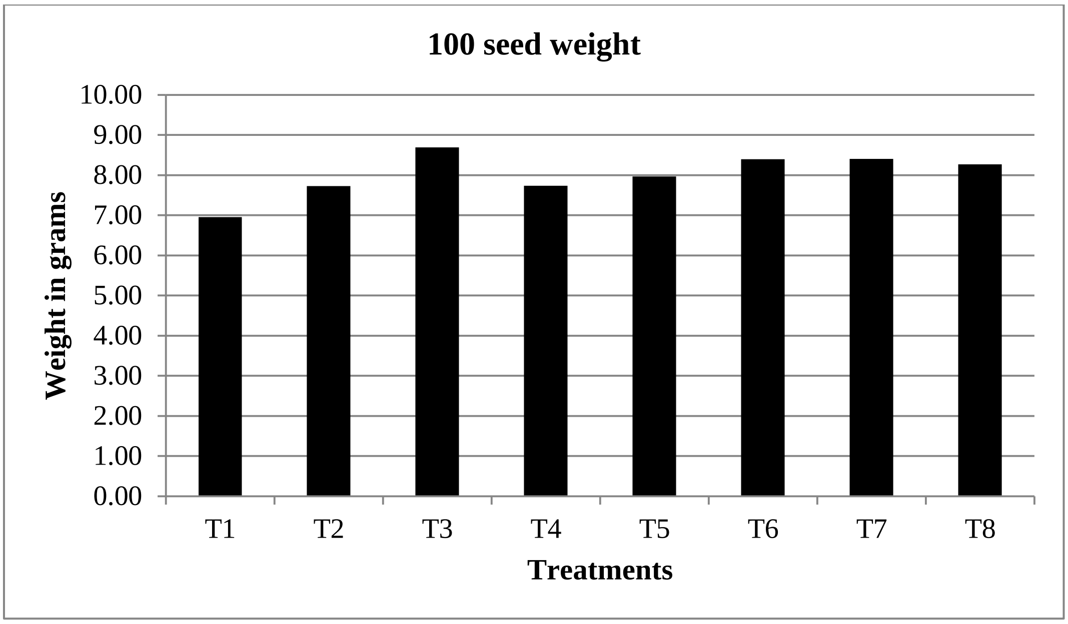

Fig. 7: 100 Seed weight (g) of sunflower variety Phule Bhaskar as influenced by different treatments

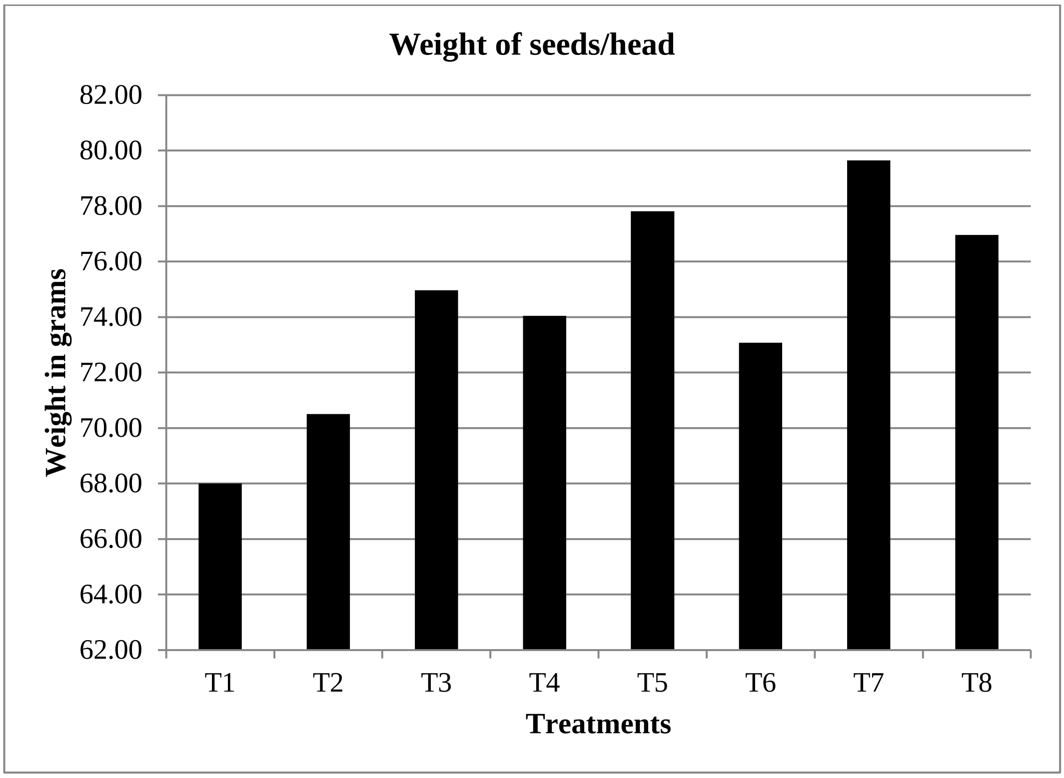

Fig. 8: Weight of seeds/head (g) of sunflower variety Phule Bhaskar as influenced by different treatments

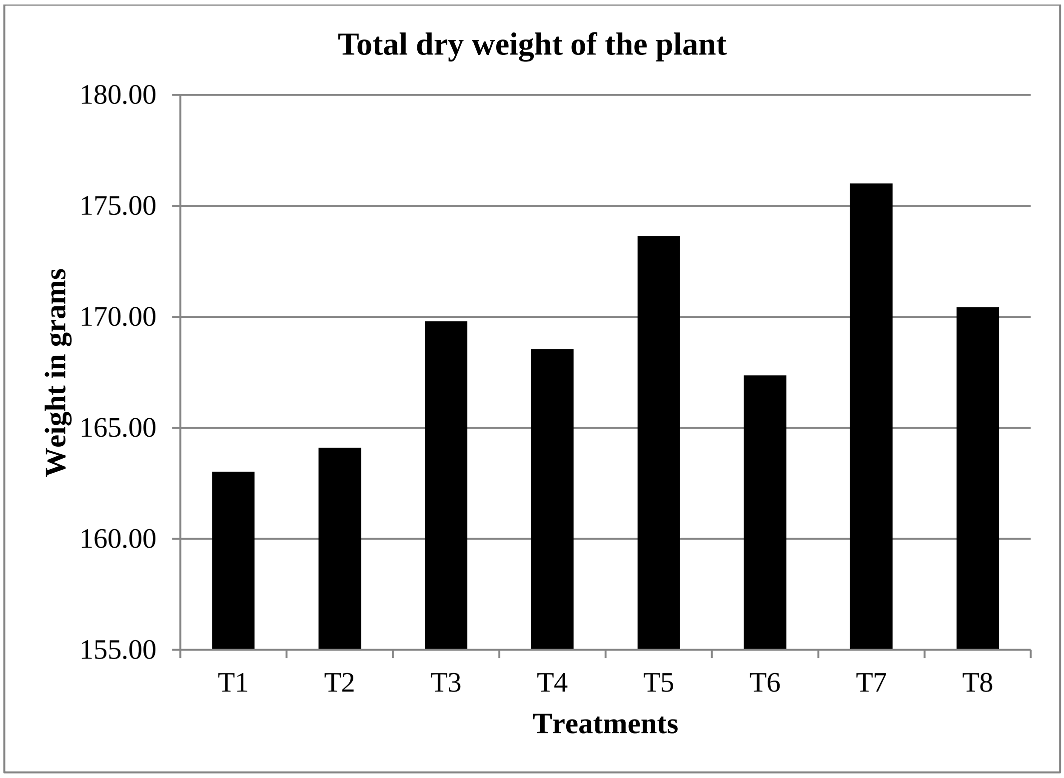

Fig. 9: Total dry weight of the plant (g) of sunflower variety Phule Bhaskar as influenced by different treatments

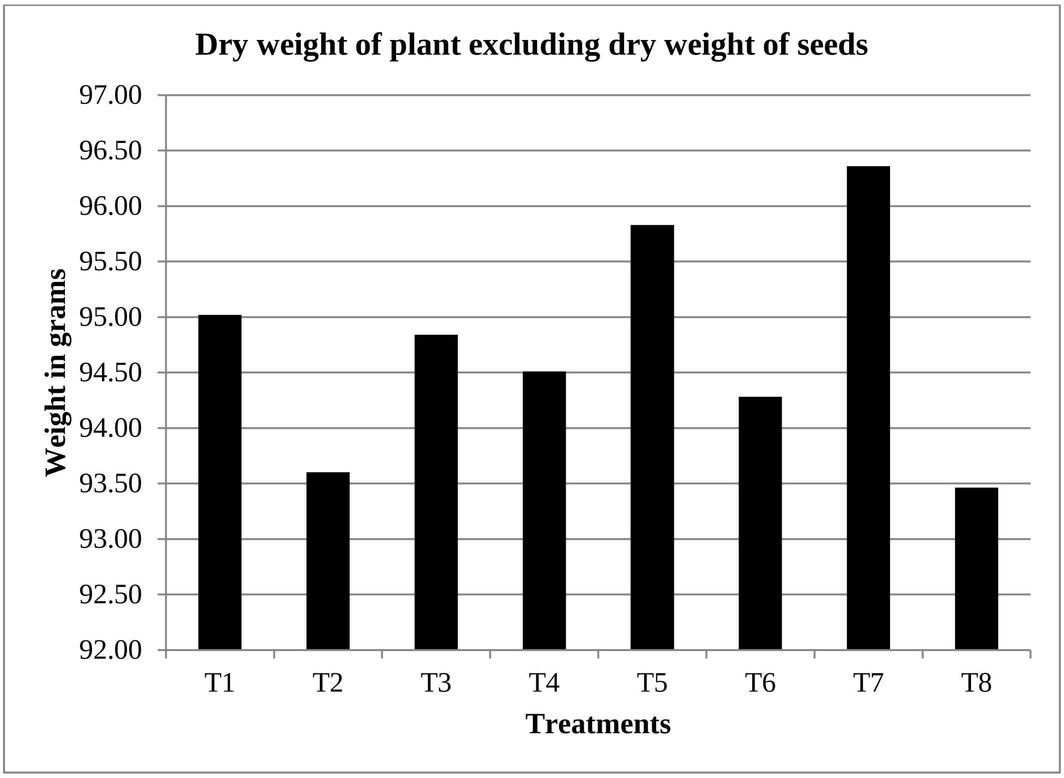

Fig. 10: Dry weight of plant excluding dry weight of seeds (g) of sunflower variety Phule Bhaskar as influenced by different treatments

4.2.10 Yield kg/plot

The data with respect to yield kg/plot is presented in Table 4. The result indicated that significant difference was observed among all the treatments over control. The treatment T_7 (0.2% boron) recorded significantly higher yield **(**1.37 kg)/plot over all the treatments. However, significantly lowest seed yield (0.99 kg)/plot was observed in treatment T_1 (control).

4.2.11 Yield q/ha

The data with respect to yield q/ha is presented in Table 4. The result indicated that significant difference observed among all the treatments for seed yield/ha. The treatment T_7 (0.2% boron) recorded significantly higher yield **(**23.84 q/ha) over all treatments. However, significantly lowest seed yield (17.18 q/ha) was observed in treatment T_1 (control). Sufficient source, a strong sink and better translocation between these two are essential for higher seed setting and yield of sunflower. The process of seed setting occurs in a short period after pollination and fertilization. These results are in accordance with the findings of Reddy *et al.* (2003), Somroo *et al.* (2007), Oyinlola (2007), Ram and Davari (2011), Al-Amery *et al.* (2011) and Tahir *et al*. (2014).

4.2.12 Harvest Index (%)

Significantly highest harvest index was recorded (45.26%) in treatment T_7 (0.2% boron) which was significantly superior over all the treatments (Table 4). Harvest index is a measure of determining productivity of a crop. These results are in accordance with the findings of Reddy *et al.* (2003), Tahir *et al*. (2014) and Khan *et al.* (2015).

4.2.13 Oil Content (%)

The data revealed that the significantly highest oil content (38.87%) was recorded in treatment T_7 (0.2% boron) which was significantly superior over all the treatments, however the lowest oil content (36.50%) was recorded in treatment T_1 (control). This might be due to after pollination and seed set, the formation of protein start and there after oil synthesis start. Whereas, maximum seed oil was found when boron was applied at bud initiation. These results are in accordance with the findings of Oyinlola (2007), Tahir *et al*. (2014) and Kawade *et al.* (2018).

Table 4: Yield kg/plot, yield q/ha, harvest index and oil content of sunflower variety Phule Bhaskar as influenced by different treatments

Sr. No.	Treatments	Yield kg/plot	Yield q/ha	Harvest Index (%)	Oil content (%)
T_1	Control	0.99	17.18	41.73	36.50
T_2	GA_3 (250 ppm)	1.11	19.32	42.98	37.42
T_3	TIBA (240 ppm)	1.27	22.10	44.15	38.71
T_4	NAA (50 ppm)	1.21	21.00	43.93	38.10
T_5	Kinetin (200 ppm)	1.33	23.15	44.84	38.60
T_6	BA (250 ppm)	1.18	20.54	43.67	37.80
T_7	Boron (0.2%)	1.37	23.84	45.26	38.87
T_8	Hand Pollination	1.14	19.73	45.16	37.51
	SE(±)	0.02	0.33	0.71	0.17
	CD @5%	0.06	1.00	2.15	0.51

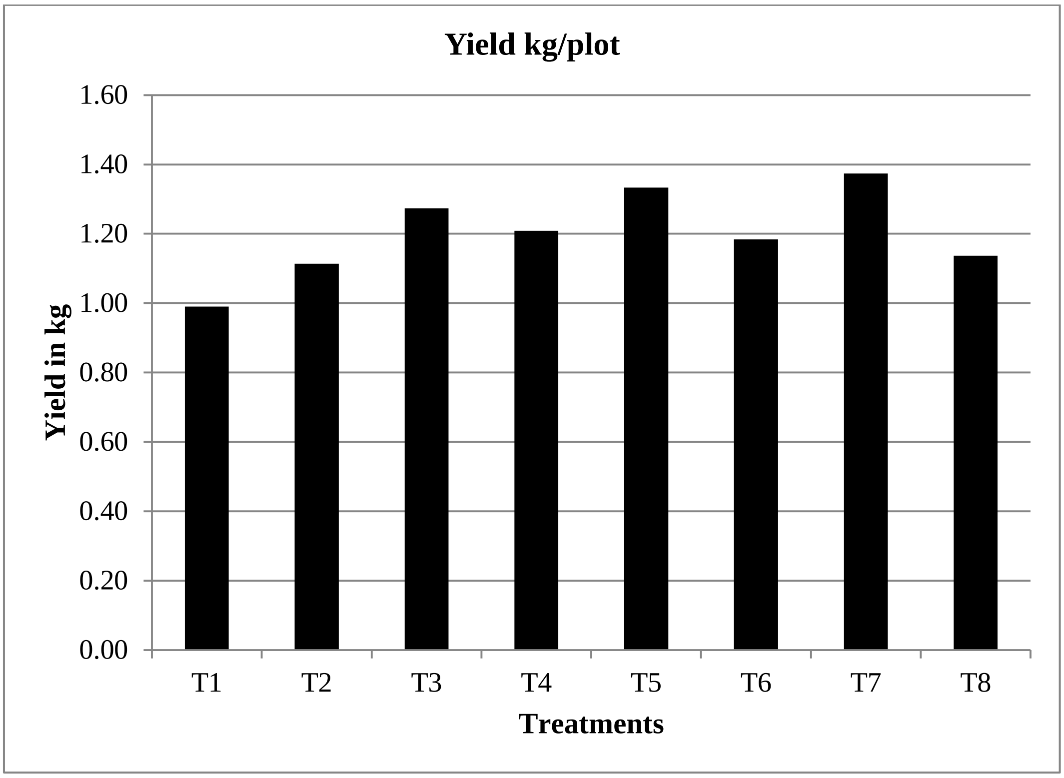

Fig. 11: Yield kg/plot of sunflower variety Phule Bhaskar as influenced by different treatments

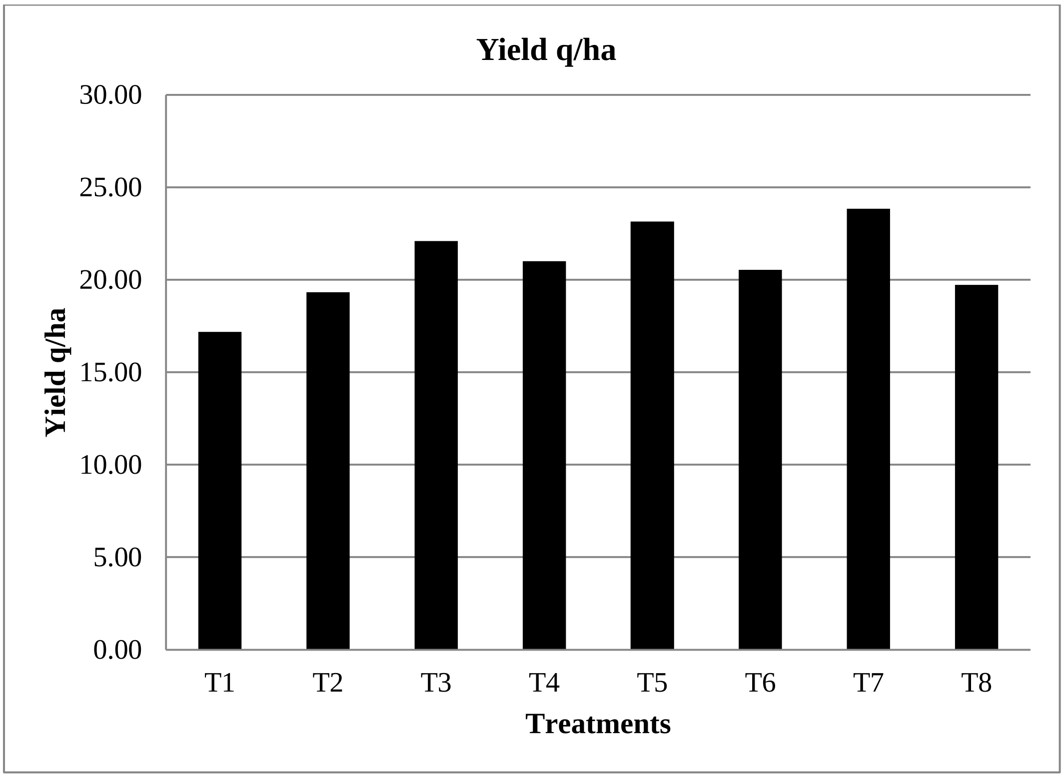

Fig. 12: Yield q/ha of sunflower variety Phule Bhaskar as influenced by different treatments

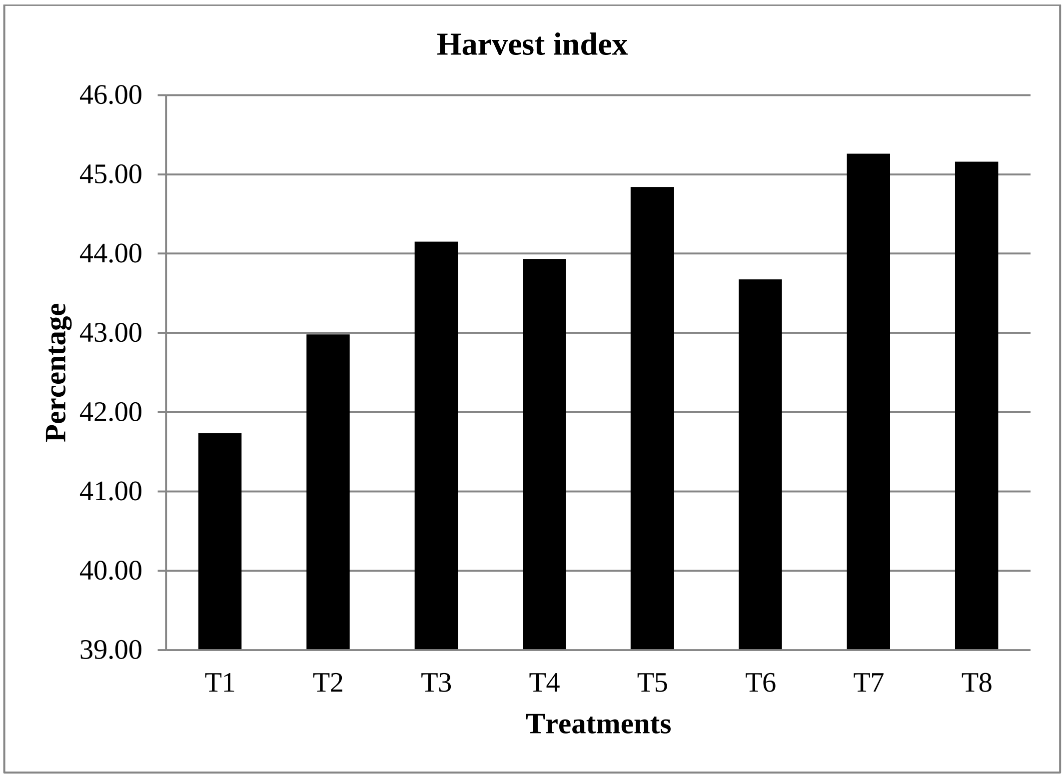

Fig. 13: Harvest index (%) of sunflower variety Phule Bhaskar as influenced by different treatments

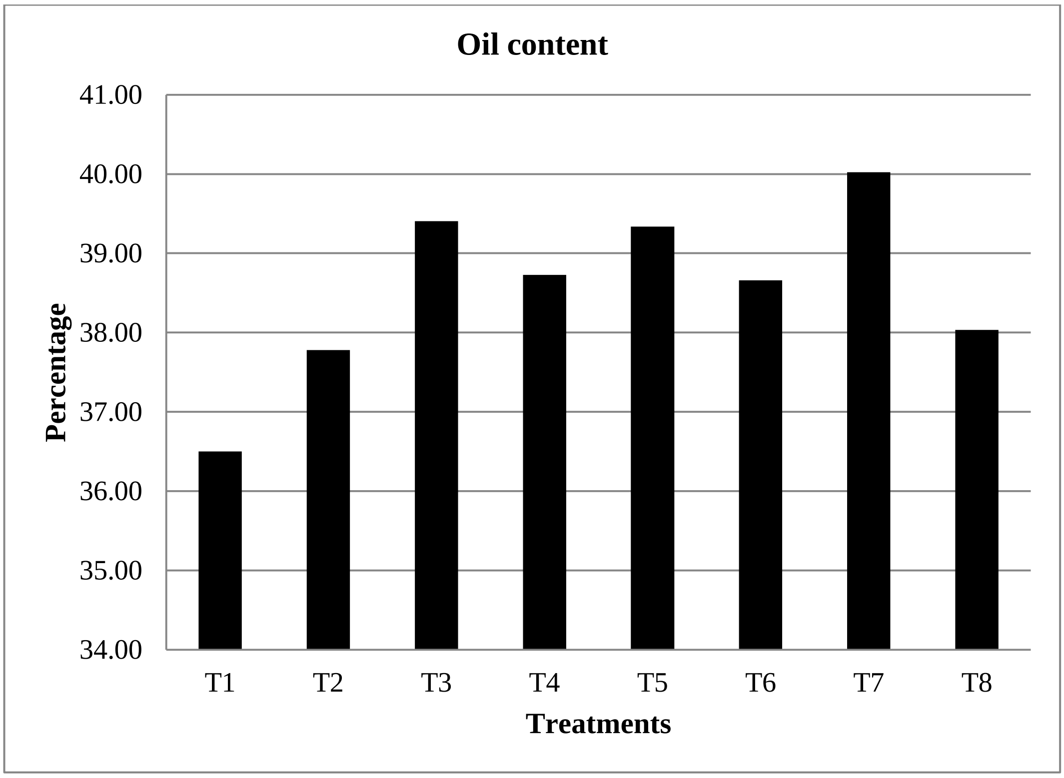

Fig. 14: Oil content (%) of sunflower variety Phule Bhaskar as influenced by different treatments

Plate 1: Field view of the experimental plot

5. SUMMARY AND CONCLUSIONS

The present study, "Effect of growth regulators on seed filling of sunflower during kharif season", was conducted during the kharif, 2017 at PGI Farm, Department of Agricultural Botany, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth., Rahuri, Dist. Ahmednagar.

The experiment was laid out in a Randomised Block Design (RBD) with three replications during kharif season of year 2017-2018. The experiment was constituted eight treatments *viz.*, T_1 [Control], T_2 [GA_3 (250 ppm)], T_3 [TIBA (240 ppm)], T_4 [NAA (50 ppm)], T_5 [Kinetin (200 ppm)], T_6 [BA (250 ppm)], T_7 [Boron (0.2%)], T_8 [Hand Pollination] were applied on the sunflower variety *viz.*, Phule Bhaskar at the time of 50% flowering and seed formation. The sunflower seeds of variety Phule Bhaskar was sown with spacing 60 cm x 30 cm and plot size 3.6 m × 3.0 m gross and 2.4 m × 2.4 m net. The sowing was undertaken on 15 July 2017 and applied recommended dose of fertilizers 40:30:30 NPK Kg/ha, with following objectives:

i) To find out appropriate growth regulator for seed filling in sunflower (*Helianthus annuus* L.)

Growth and yield parameters recorded on sunflower are days required for bud initiation, days required for 50% flowering, days required for maturity, head diameter (cm), total number of seeds/head, total number of filled seeds/head, total number of unfilled seeds/head, seed filling percentage (%), weight of seeds/head (g), 100 seed weight (g), total dry weight of the plant (g), yield (kg/plot), yield (kg/ha), harvest index (%) and oil content (%). The important findings obtained from the experiment are summarized in this chapter.

1) Phenological Studies:

Among all the treatments, treatment T_7 (0.2% boron) recorded earlier flowering and took minimum days to maturity as compared to other treatments.

2) Yield and Yield Contributing Characters:

As regards the yield and yield contributing characters *viz.*, head diameter (cm), total number of filled seeds/head, total number of unfilled seeds/head, total number of seeds/head, seed filling percentage, weight of seeds/head (g), total dry weight of the plant (g), dry weight of plant excluding weight of seeds (g), yield kg/plot, yield q/ha, harvest index (%) and oil content (%), among all the treatments, treatment T_7 (0.2% boron) resulted best performance which was significantly superior over control.

In case of 100 seed weight, the treatment T_3 (TIBA 240 ppm) recorded significantly highest seed weight (8.69 g) followed by treatment T_7 (0.2% boron) (8.40 g) showed best performance.

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*** Originals not seen**

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IN

PLANT PHYSIOLOGY

2018

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