STUDIES ON MACRO-PROPAGATION OF BANANA (*Musa* spp.)

By

VINAY KUMAR

MASTER OF SCIENCE (AGRICULTURE)
HORTICULTURE (FRUIT SCIENCE)

DEPARTMENT OF HORTICULTURE

Dr. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY,PUSA (SAMASTIPUR) BIHAR – 848 125, INDIA

Regd. No. M/HORT/443/2019-20

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A THESIS SUBMITTED TO

Dr. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY, PUSA, BIHAR

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DEPARTMENT OF HORTICULTURE

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Dedicated to

To my parents

Shri Bhan Singh & Smt. Rajabeti,

My elder brothers Lovkush,

All my Teachers

Family & Friends from childhood to adulthood.

"Whose faith,

blessing, sacrifices &

perpetual affection

always inspired me

to attain high ambition in life"

... Vinay Kumar.

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PG College of Agriculture
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Dr. Asish Kumar Panda
Assistant Professor

Dated.....27../.07../2021

Certificate

This is to certify that the work embodied in the thesis entitled **"Studies on Macro-propagation of Banana (*Musa* spp.)"** submitted by **Mr. Vinay Kumar** in the partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (HORTICULTURE) FRUIT SCIENCE** of Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur) Bihar, is a record of bona fide research work carried out by him under my supervision and guidance. The results embodied in this thesis have not been submitted to any other university or institution for the award of any degree or diploma. The assistance and facilities received during the course of this investigation and sources of information have been duly acknowledged.

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ABSTRACT

The present investigation entitled "Studies on Macro-propagation of Banana (*Musa* spp.)" was carried out during 2020-21 in the research farm of All India Co-ordinated Research Project on for Fruit crops research field, Department of Horticulture, Dr. Rajendra Prasad Central Agriculture University, Pusa, Samastipur (Bihar).

The experiments was laid out in Two-factors Completely Randomized Design (CRD) with eight different types of treatment *viz.,* T_1 (Sawdust), T_2 (Sawdust + *Azotobacter*), T_3 (Sawdust + *Trichoderma*), T_4 (Sawdust + *Azotobacter* + *Trichoderma*), T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*), T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*), T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*), T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*) which were replicated five times.

The results of the investigation that, among the different growing media of T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*) gave better performance in macro-propagation of banana on growth parameters.

With reference to different propagation media, Sawdust (50%) mixed with Banana fibre waste (50%) & *Trichoderma* recorded maximum survival percentage (94.79 %), minimum days taken primary bud (21.45), secondary bud (46.91) & tertiary bud emergence (58.99), and maximum number of primary shoots (4.21),

secondary shoots (7.16) & tertiary shoots (19.91). Same growing media also recorded minimum days taken for root emergence (17.61 days), maximum number of roots per shoot (161.10), primary roots (24.89), secondary roots (46.32), tertiary roots (89.90) & highest root length (21.88 cm).

Keywords: Macro-propagation, sawdust, banana fibre waste, *Trichoderma*, *Azotobacter* and cocopeat.

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ABBREVIATIONS/NOTATIONS USED FOR UNITS

%	:	Per cent
/	:	Per
℃	:	Degree Celsius
et al.	:	and co workers
Temp.	:	Temperature
Max.	:	Maximum
Min.	:	Minimum
Avg.	:	Average
cm	:	Centimeter
M	:	Meter
G	:	Gram
Kg	:	Kilogram
ha.	:	Hectare
Mt.	:	Million tonnes
&	:	And
@	:	At the rate
Sr.No.	:	Serial number
Viz.	:	Namely
Vs	:	Versus
X	:	Cross
i.e.	:	That is
Fig.	:	Figure

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CHAPTER - I

INTRODUCTION

INTRODUCTION

Banana (*Musa* spp.) is one of the most valuable fruits. Banana (*Musa* spp.), often known as the "Apple of Paradise," is a fruit that belongs to the Musaceae family, section *Eumusa,* and order Zingiberales. It is one of the oldest and most extensively produced fruits known to mankind. It's possible that they were farmed as early as 1000 B.C. Alexander the great found banana in India in 327 B.C. It is as old as the Indian civilization and antiquity can be traced from its mention in Ramayana (2029 C, 'Kautilya' Arthashastra, (300-400 B.C.) and its presence in paintings, sculptures of Ajantha and Ellora.

Banana is derived from the Arabic word "BANANA," which meaning "finger." Other names for it include 'Adam's fig,' 'Kalpataru,' 'Tree of Wisdom,' and 'Apple of Paradise'. Bananas were once known as the "Fruit of the Wise Men" in India (Bose, T. K. 2001).

The banana originated from South East Asia, a region considered as the primary center of diversification of the crop and where the earliest domestication occurred (Simmonds *et al.,* 1962). The banana is a popular tropical fruit (Samson *et al.,* 1992).

The two major progenitors of cultivated banana cultivars are *Musa acuminata* (AA genome) and *Musa balbisiana* (BB genome) (Robinson *et al.,* 2007). Many cultivated bananas have been discovered to be triploid, with a genomic composition of AAA (primarily sweet dessert bananas) accounting for just a small percentage of global output. Bananas are only edible in tropical and neotropical areas, generally between 300N and 300S latitudes (Morton *et al.,*1987).

One gram of fruit pulp is a rich source of protein –12.80 mg, carbohydrates – 240 mg, soluble sugar –86 mg, fiber –8.2 mg, ash –12.8 mg, calcium –0.118 mg, phosphorus –0.36 mg, iron –0.015 mg, thiamine –0.0028mg, riboflavin –0.0016mg, niacin –0.012 mg, ascorbic acid –0.50 mg, tryptophan –0.017 mg, lysine –0.580 mg, methionine –0.090 mg. The banana was to be an essential diet for improving the health of malnourished children because it includes a high amount of protein and fibre (Adeolu *et al.,* 2013).

The total area and production of bananas in the world during 2018 is estimated at 5728680 ha and 115737861 ton. The largest banana production countries are

Turkey, Nicaragua, and Indonesia, South Africa, and India 19th position in the world (Anonymous, 2018, FAO).

Banana is an important fruit crop of many tropical and sub-tropical regions of India. The total area, production, and productivity of bananas in India during 2018-2019 are estimated at 866000 Ha, 30460000 MT. The largest banana production states are Andhra Pradesh, Gujarat, Maharashtra, Tamil Nadu, and Bihar (Anonymous, 2018-2019, National Horticulture Board).

In Bihar, the total area, production, and productivity of bananas are 35.15 thousand hectares, 15.5 million tonnes, and 44.12 tonnes per hectare, respectively (Anonymous, 2019, National Horticulture Board).

Grand Naine (AAA) is a famous cultivar that is recognized for its unique fragrance and fruit quality. It is well accepted and ideal for export because to its high quality and flavour. The fruit has a great scent and a bright golden colour after ripening, which attracts a large number of visitors. Tissue culture businesses are now the most common source of planting material, and they are widely recognized by farmers due to the superiority of tissue culture plants over traditional rhizome sucker plantation (Singh *et al.,* 2014).

In Bihar, Alpan (AAB) is one of the most popular cultivars. The cultivar Alpan (AAB) is a synonym for the cultivar Poovan. It's a perennial crop that's grown all throughout the country. It is the most popular cultivar in the southern and north-eastern states. When young, it has pink pigmentation on the ventral side of its midrib, which distinguishes it from other cultivars. It produces big bunches weighing 20-40 kg each, with short, stout fruits with a prominent beak that are tightly packed. The number of fruits per bunch varies between 150 and 300. Fruits are slightly acidic, and the yield lasts 16-17 months. The banana-streak virus, on the other hand, has braked on it.

Across India, the expansion of banana cultivation is greatly hindered by weed, diminishing soil fertility, drought, pest and diseases, and social-economic factors. Another stumbling block to large-scale banana and plantain production, as well as the development of existing plantations, is the difficulty in acquiring enough, high-quality planting materials. (Baiyeri *et al.,* 2000; Schill *et al.,* 2002; Nkendah *et al.,* 2003).

Suckers grown in a traditional manner can potentially be a source of soil-borne diseases. *Fusarium oxysporum sp. cubense*, the cause of *fusarium* wilt, nematode, and banana corm weevil are examples (*Cosmopolites sordidus*). Although the tissue culture (TC) propagation technology has been around for a decade, it has yet to help the bulk of small-scale farmers. This is due to the expensive cost and high level of competence required to utilize the technology (Vuylsteke *et al.*, 1998; Sahijram *et al.*, 2003).

Macro-propagation is one such technology that, if used properly, may significantly increase banana production. The simple method includes stimulating the lateral development of numerous latent buds in a corm under a controlled environment of humidity and temperature. In four months, one corm can produce 10 to 30 plantlets, although the results will vary depending on the banana cultivar and the type of bud manipulation used. Scarification of buds can boost suckering by a ratio of two to ten. (Tenkouano *et al.*, 2006). Macro-propagation is a hybrid model of tissue culture and the conventional suckers-producing method (Lorenzo, 2008). Unlike TC, macro-propagation is inexpensive and simple, thus it may be done on a farm.

Due to its triploid nature, bananas are mostly parthenocarpy (produce fruit without fertilization) and must be propagated by vegetative methods. Plantlets produced by TC and macro-propagation, as well as spontaneously regenerated suckers, are used to propagate them.

Farmers use existing plantation planting material to develop or extend plantations through natural regeneration. Farmers choose the sucker's cultivar, age, and size (Staver *et al.*, 2010). This approach is cost-effective because to the ease with which the suckers may be obtained. It is extensively used, although it poses a danger of transmitting illnesses and pests, but disease transmission may be decreased by treating suckers. Furthermore, the suckers are not consistent, the quantity of plantlets produced is limited, and there is a significant likelihood that farmers will be unsure about the variety. These variables might cause yield inconsistency.

Macro-propagation is based on a simple, cost-effective approach that can be deployed quickly with little resources and training. The initial initiatives were aimed at determining the feasibility and obstacles of implementation, as well as measuring market reaction. The inexpensive cost of the plantlet resulted in strong adoption in all

of the areas where it was introduced, according to the study. Macro-propagation was shown to have the ability to expand access to low-cost, high-quality plantlets (Mwangi *et al.,* 2008). As a result, more study is needed to examine the technology's success in producing healthy plantlets in order to encourage farmers to embrace it.

Repression of the apical meristem stimulates the regeneration of the lateral meristem in macro-propagation, a cost-effective method (Sajith *et al.,* 2014). Suckering rate may be boosted by complete/partial decapitation on a field-grown plant or the detached corm method, and sawdust is the best substrate with the highest water holding capacity over other substrates such as rice hull, cocopeat, sand, and so on (Baiyeri *et al.,* 2005).

The use of macro-propagation to multiply banana planting material is a low-cost option with a lot of potential for producing high-quality planting material in bananas. Incorporating additives such as bio-fertilizers and growth hormones not only improved regeneration but also stimulated plantlet growth and development, lowering post-transplant shock and increasing percent survival in the field.

In comparison to micro-propagation, there has been little study done and less information available on macro-propagation strategies. The quality and quantity of plantlets produced in the shortest amount of time determine the appropriate media for macro-propagation. One of the reasons for the low yield is a shortage of high-quality plantlets. Macro-propagation will boost banana production by delivering enough high-quality seedlings on time, reviving the industry. Small-scale farmers will benefit from increased food security and income production as a result of this.

With these considerations in mind, the current study, named "Studies on Macro-propagation of Banana (*Musa* spp.)," has the following goals.

1.1. Objectives

- To standardize and validate the macro-propagation technique in bananas under the agroclimatic condition of north bihar.
- To identify the best suited growing media with reference to bio-fertilizer treatments for the macro-propagation technique in bananas.
- To find-out the benefit cost ratio of the macro propagation technique for production of quality planting materials in banana.

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CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITRATURE

2.1. Effects of different growing media on survival percentage

Baiyeri *et al*., (2005) recorded the impact of renewal media on the quantity, quality, and survival of plantlets during the pre-nursery and early-nursery stages. Plantlet survival is determined by the genotypes of the plants, the regeneration media used, and the rooting stage of the plantlets at the time of excision. Plantlets that were excised with root system had a higher survival rate in most instances. However, all 'Nsukka Local' plantlets that were germinated in sawdust but were rootless survived. Plantlets grown in sawdust (regardless of rooting stage) survive somewhat better than those grown in ricehull.

Kashyap *et al*., (2011) assessed the impact of the growing medium on the hardening of in-vitro grown 'gloxinia' and 'saintpaulia' plantlets under low-cost polytunnels. The objective of the study was to standardize the hardening media for 'gloxinia' (Sinningiaspeciosa) and 'saintpaulia' uniform (Saintpauliaionantha). The experiment was conducted with four mediums like cocopeat, cocopeat with perlite (3:1), soil with sand (1:1), & perlite. Observations were recorded after 10 weeks of hardening. The results revealed that cocopeat & perlite (3:1) was the optimum hardening medium, for gloxinia and saintpaulia with survival percentages of 79.02 and 89.77, respectively.

Dzomeku *et al*., (2014) tested five cultivar of *Musa sapientum* (False Horn) namely "Asamienu (True Horn), Oniaba (intermediate French plantain) and FHIA-21 (tetraploid hybrid plantain)" to know their response to the PIBS technique. The least average of healthy plantlets were produced by cultivar Oniaba. Apantu (False Horn) yielded nearly 75 healthy planting materials on average. On the other hand, the hybrid FHIA-21 produced an average of 85 healthy planting materials. Asamienu (True Horn) produced the healthiest seedlings out of around 90 good planting materials.

Dayarani *et al.*, (2013) studied that, the composted sawdust was used as initiations medium. Before hardening, the plantlets that lacked a suitable root system were treated with IBA (90.25%), which resulted in robust development during the acclimatisation period. T_3 (Sucker with Decapitation of Rhizome) had the highest percentage of rooting, with 92.4 percent survival. Decapitation of the rhizome and

treatment with (0.04%) BAP resulted in good results, with a great number of buds and a high rate of reproduction.

Esakkimuthu *et al.,* (2017) found that the effects of different growing media on the growth characteristics of the banana cv. POOVAN, finding that the plantlets transplanted in growing media FYM was employed as the regeneration medium with VAM resulted in a higher proportion of plants surviving.

Vasane *et al.,* (2006) studied on modification of secondary hardening procedure of plantlets in case of Banana (*Musa paradisiaca* var Grand Naine) and rated the importance of well-hardened planting material in achieving the best possible survival rate when transplanting tissue cultured derived plants from the shade house (secondary hardening).

Ahmed *et al*., (2014) investigated the procedure of hardening and adaptation of micro-propagated plantlets of banana cv. Grand Naine. The maximum survival (100.00 %) during transplanting was recorded when transplanting was done at the age of 4 weeks old plantlets. Plantlets were individually covered with glass beakers and stored in the culture room to ensure highest survival through hardening. The findings showed that out of various medium used for hardening of plantlets, the medium soil: sand and FYM (2:1:1 v/v/v) showed 100% survival.

2.2.1 Effects of different growing media on days taken for primary bud emergence

Sajith *et al*., (2014) studied the decapitation procedure (macro-propagation) with regard to improve the efficiency of decortications in elite cv. Bangladesh Malbhog with ingredients similar to plant growth hormones and bio-fertilizers. Rhizome weighing 1.0-1.5 kg was used as planting material, along with sawdust. The combination of AMF and *Trichoderma viride* produced the earliest bud regeneration in 28.3 days, followed by BAP with *Bacillus subtilis* in 29.70 days, and AMF in 30 days. For the rest of the treatments, the time taken for bud initiation followed the same pattern.

Baiyeri *et al*., (2005) recorded the effect of regeneration media on number, quality and survival of plantlets at pre nursery and early nursery stage. The findings revealed that induction media had relatively similar effects on the majority of the characteristics studied. Ricehull, on the other hand, had a significantly (P0.05) shorter

period to the development of the second and third plantlets. ‘FHIA 17' (a dessert banana hybrid) had the lowest days to first and fifth plantlet emergence, whereas ‘PITA 25' had the longest (a plantain hybrid). The first three plantlets appeared earlier in the landrace plantain (‘Agbagba') than in the dessert banana landrace (‘Nsukka Local').

Sannigrahi *et al.,* (2017) studies on eight commercial cultivars of banana namely “Martaman (AAB), Grand Naine (AAA), Champa (AAB), Robusta (AAA), Kanthali clone-1 (ABB), BagdaKanthali (ABB), BaishChhara (ABB), and Behula (ABB)” were effectively induced by macro-propagation technology for large number of healthy planting materials. Healthy suckers of 4 to 5 months old were decapitated and paired with corms, which were then planted in a growth media bed (containing 2 kg sawdust + 30g *Trichoderma viride*/*Bacillus subtilis* + 30g VAM per corm) and treated weekly with a 25 ppm 6-benzyl amino purine (BAP) solution. Initiation of primary shoot took 19.75 days in the Grand Naine variety and 28.25 days in the Bagda variety.

Thungon *et al.,* (2015) evaluated the effect of suitable initiation media on macro-propagation of Malbhog banana under polyhouse. Sawdust, paddy husks and cocopeat were used as three different growing media. Cocopeat had the quickest primary sucker emergence (18.57 days). This is the first report of Malbhog banana macro-propagation utilizing cocopeat as a growing medium.

Tchoa *et al*., (2016) observed effects of substrates on massive propagation of plantain. The purpose of this research was to determine the best conditions for mass-producing healthy planting materials. The results demonstrated that dehydrated suckers larger than 750 g produce shoots regardless of the culture substrate applied; with the highest number of shoots observed with dehydrated suckers larger than 750 g. Suckers of this weight who were not dehydrated have a longer lifespan (124-140 days). Shoot induction was faster with non-dehydrated suckers on fibre coco (12 days) and dehydrated suckers on mix sawdust (12 days) among the substrates examined (15 days).

Anonymous (2014) carried out an experiment at Jorhat, Mohanpur, Pusa, Kannada, Bhubaneswar, Kovvur, Coimbatore, Jalgaon, Arabhavi, and Gandevi to assess the effect of different medium on macro-propagation of banana. Results

revealed, the early bud initiation was seen in T_6 [Sawdust with VAM (30g), BAP (4ml) & *Bacillus subtilis* (30g)] in the Martaman (19.5 days) and Grand Naine (18.2 days) and the treatments T_6 [Sawdust with VAM (30g), BAP (4ml) & *Bacillus subtilis* (30g)] produced the most primary buds in Martaman (3.5) and Grand Naine (5.1).

Dayarani *et al.,* (2013) noted that decapitation of the rhizome and treatment with 0.04 percent BAP resulted in a large number of buds and a high rate of regeneration. Treatment (Sucker + Rhizome Decapitation) took considerably less time to initiate the first bud than the other two treatments since it took just 30 days to initiate the first bud, whereas the other two treatments took more than 40 days.

Samanta *et al*., (2016) conducted an experiment for standardization of macropropagation in banana cultivars with seven treatments i.e. "T_1 [Sawdust + VAM (30g]), T_2 [Sawdust + *Trichoderma viride* (30g)], T_3 [Sawdust + VAM (30g) + *Trichoderma viride* (30g]), T_4 [Sawdust + IBA (dipping in 0.25% solution) + Azospirillum (30g]), T_5 [Sawdust + BAP (4ml) + *Bacillus subtilis (*30g]), T_6 [Sawdust + VAM (30g) + BAP (4ml) + *Bacillus subtilis (*30g]), along with a control as T_7". The results showed that applied Sawdust with VAM (30g), BAP (4ml) & *Bacillus subtilis* (30g) resulted in the shortest days for bud initiation, which was shown to be superior to the 13 other treatments tested. Bantala demonstrated the shortest time from planting to primary bud initiation (25.13 days).

Pujar *et al*., (2017) conducted an experiment to determine varietal response on plantlet regeneration in banana using macro-propagation. Ney Poovan, Rajapuri, and Grand Naine, three commercially produced kinds were chosen for the experiment. Standardized growing media (from previous experiments) were used, including a 1:1 mixture of Sawdust and FYM, as well as a chemical treatment of BAP 40 ppm (from previous studies). Finally, the minimum days taken for initial bud emergence (30.80 days) in Ney Poovan, which is comparable to Grand Naine, were discovered (34.71 days).

Kindimba *et al.,* (2014) experimented and findings suggest that, concentration of BAP at 1.5 mg/l reduced the number of days to first shoot emergence of 15.78 days significantly followed by BAP at 3.0, 6.0 and 0.0 mg/l with 25.18, 28.39 and 36.43 days, respectively.

Thiemele *et al*., (2015) reported that, decorticated banana corms were sprayed when planted in sterilised soil in a high humidity plastic tunnel, decorticated banana corms were sprayed with BAP solution every two weeks. According to the data, BAP treatment at 40 mg/l considerably shortened the emergence time of shoots at 20 days, compared to25.1, 28.3, and 28.5 days for the other treatments and control, respectively.

2.3. Effect of growing media on number of primary shoots

Thungon *et al., (*2015) noticed that, the suitable initiation media for macro-propagation of Malbhog banana. Sawdust, paddy husks and cocopeat were used as three different growing media. The highest number of primary (4.17) per corm were found in T_4 treatment (BAP 0.04%).The treatment combination of cocopeat and BAP (0.04%) could be recommended for production of quality planting materials of 'Malbhog' banana through macro-propagation.

Sajith *et al*., (2014) investigated decapitation approaches (macro-propagation) to improve decortication efficacy in choice cv. Bangladesh Malbhog uses bio-fertilizers and growth hormones as well as other chemicals. Suckers weighing 1.0-1.5 kg were used as substrate, along with sawdust. In comparison to control, treatment T_{11} (Bacillus subtilis + BAP) produced the most primary buds (3.77 buds/sucker).

Anonymous (2014) experiment was carried out in Jorhat, Mohanpur, Pusa, Kannada, Bhubaneswar, Kovvur, Coimbatore, Jalgaon, Arabhavi, and Gandevi, according to the paper. The treatments T_6 [Sawdust with VAM (30g), BAP (4ml) & *Bacillus subtilis* (30g)] produced the most primary buds in Martaman (3.5) and Grand Naine (5.1) according to Mohanpur centre.

Pujar *et al*., (2017) investigated the effect of varietal response on plantlet regeneration in banana using macro-propagation. Ney Poovan, Rajapuri, and Grand Naine, three commercially grown cultivars were chosen for the experiment. Standardized growing media (from previous studies) were employed, including a 1:1 mixture of Sawdust and FYM, as well as a chemical treatment of BAP 40 ppm (from previous studies). Grand Naine has generated a considerably larger number of primary buds per corm than the other varieties/cultivars used (3.74).

Sannigrahi *et al.,* (2017) studies on eight commercial cultivars like "Grand Naine (AAA), Robusta (AAA), Martaman (AAB), Champa (AAB), Kanthali clone-1

(ABB), Bagda Kanthali (ABB), Baish Chhara (ABB), and Behula (ABB)" were effectively induced by macro-propagation technology for large number of healthy planting materials. Induction of primary shoot took 19.75 days in the Grand Naine variety and 28.25 days in the Bagda variety. In the AAA group, the number of induced primary shoots was larger (3.23 to 3.40/corm), compared to the AAB (2.70-2.90 shoots/corm) and ABB (2.20-2.50 shoots/corm) groups.

2.4. Effects of different growing media on number of secondary shoots

Sajith *et al*., (2014) studied the decapitation methods (macro-propagation) with respect to improve the effectiveness of decapitated in elite cv. Bangladesh Malbhog using of bio-fertilizers and plant development hormones. Suckers weighing 1.0-1.5 kg were used as substrate, along with sawdust. In comparison to the control, all treatments were effective for plantlet generation and improved bud proliferation, growth, and root profiles. In comparison to control, treatment T_{11} (*Bacillus subtilis* + BAP) produced the maximum number of secondary buds (5.70 buds/sucker).

Thungon *et al., (*2015) noticed that, the suitable initiation media for macro-propagation of Malbhog banana under polyhouse. Sawdust, paddy husks and cocopeat were used as three different growing media. The highest number of secondary suckers (8.35) per corm were found in T_4 treatment (BAP 0.04%).The treatment combination of cocopeat and BAP (0.04%) could be recommended for production of quality planting materials of 'Malbhog' banana through macro-propogation .

Pujar *et al*., (2017) conducted a trial to know various genotypes performance on plantlet renewal through macro-propagation in banana. Ney Poovan, Rajapuri, and Grand Naine, three commercially cultivated varieties were chosen for the experiment. Standardized growing media (from previous experiments) were used, including a 1:1 mixture of Sawdust and FYM, as well as a chemical treatment of BAP 40 ppm (from previous studies). Grand Naine produced a significantly higher number of plantlets after secondary decapitation than Rajapuri (15.02 and14.25, respectively) among the different varieties/cultivars used.

2.5. Effects of different growing media on days taken for tertiary bud emergence

Thungon *et al., (*2015) noticed that, the suitable initiation media for macro-propagation of Malbhog banana under polyhouse. Sawdust, paddy husks and cocopeat

were used as three different growing media. The treatment combination of cocopeat and BAP (0.04%) could be recommended for production of quality planting materials of 'Malbhog' banana through macro-propogation. Cocopeat had the quickest tertiary sucker separation (82.55 days).

2.6. Effects of different growing media on number of tertiary shoots

Sajith *et al*., (2014) studied the decapitation methods (macro-propagation) with respect to increase the efficacy of decortications in best cv. Bangladesh Malbhog using bio-fertilizers and plant growth hormones. The substrate was made out of suckers weighing 1.0-1.5 kg and sawdust. In compared to control, the treatment, T_{11} (*Bacillus subtilis* with BAP) produced the most tertiary buds (7.33 buds/sucker).

Lepoint *et al.,* (2013) revealed that, viable corm produced large number of shoots after scarification (productivity) were recorded. Sawdust and rice hull performed significantly better than coffee husks as initiation substrates. In contrast, 'Igisahira' produced 22 shoots per corm, while 'FHIA-17' produced up to 25 and 'Mzuzu' produced up to 28.

Sannigrahi *et al.,* (2017) studies on eight commercial cultivars like Grand Naine, Robusta, Martaman, Champa, Kanthali clone-1, BagdaKanthali, BaishChhara, and Behula, were successfully induced by macro-propagation technology for healthy planting materials with large number of tertiary shoots. Suckers were beheaded and associated with corms, which were then planted in a growth media bed (containing 2 kg sawdust + 30g *Trichoderma viride/Bacillus subtilis* + 30g VAM per corm) and weekly treated with a 25 ppm 6-benzyl amino purine (BAP) solution. Grand Naine (24.23) generated the most tertiary shoots per corm, whereas Kanthali produced the least (9.61).

Thungon *et al., (*2015) noticed that, the suitable initiation media for macro-propagation of Malbhog banana. Sawdust, paddy husks and cocopeat were used as three different growing media. Highest number of primary (3.88), secondary (8.26) and tertiary suckers (23.84), cocopeat might be considered as the best growing medium for macro-propagation. The highest number of tertiary suckers per corm is (24.02) were found in T4 treatment (BAP 0.04%).

Pujar *et al*., (2017) experiments were conducted to recognize better cultivar for healthy and maximum number of plantlets regeneration through macro-propagation in

banana. Three popular cultivated varieties were selected for experiment *viz*., Ney Poovan, Rajapuri and Grand Naine. Conventional growing media (from previous experiments) were used, including a 1:1 mixture of Sawdust and FYM, as well as a chemical treatment of BAP 40 ppm (from previous studies). Grand Naine (18.71) and Rajapuri (18.71) have generated the most plantlets per corm among the several varieties/cultivars used (18.00).

Baruah *et al.,* (2015) suggested that, using macro-propagation to mass propagate bananas is a farmer-friendly method for disease-free planting substance production in the field. Transplanting detopped and in October, decorticated corms weighing 1-1.5 kg were inoculated with Bacillus subtilis initiation media and corms treated with 40 ppm BAP, resulting in the production of 25-27 numbers of standardised tertiary suckers ready for field planting by March-April, which is the recommended planting time for Assam.

Dayarani *et al.,* (2013) found that decapitation of the corm and treatment with 0.04 % BAP produced in a maximum number of buds and a high rate of renewal. Treatment (Sucker + Rhizome Decapitation) took considerably each main bud produced a large number of tertiary buds (3.6). As an initiating media, composted sawdust was used.

Kindimba *et al.,* (2014) reported that most favourable BAP application for in vivo macro propagation of the French plantain cv. 'Itoke Sege'. BAP concentrations of 1.5 mg/l increased sucker productivity considerably ($P<0.05$) with 17.11 suckers per corm, followed by BAP concentrations of 0.0, 3.0, and 6.0 mg/l with 15.23, 13.08, and 12.96 suckers per corm, respectively.

Garcia *et al.,* (2016) stated that plant growth regulators were used in cv. Williams macro-propagation in a thermal chamber. Treatments included 6-Benzyl amino purine at concentrations of 0, 20, 40, and 80 mg/l and a bio stimulant based on algal extract at dosages of 0, 20, 40, and 80 ml/corm. At a dosage of 40 mg/l, the 6-BAP factor showed substantial changes (p0.0001), with the maximum multiplication rate (47.28 plantlets/corm) obtained.

2.7. Effects of different growing media on days taken for root emergence

Sannigrahi *et al.,* (2017) studies on eight commercial cultivars like Grand Naine, Robusta, Martaman, Champa, Kanthali clone-1, BagdaKanthali, BaishChhara,

and Behula, were effectively induced by macro-propagation technology for large number of healthy planting materials. Primary roots were induced two weeks after treatment in the AAA group.

2.8. Effects of different growing media on number of roots per shoots

Al-Amin *et al.,* (2009) found that different concentrations of BAP on virus-free plant regeneration, shoot multiplication, and varied concentrations of IBA were employed at 10, 20, and 30 DAI. 7.5 mg/l BAP+0.5 mg/l NAA was used in various quantities.

2.9. Effects of different growing media on number of primary roots

Sannigrahi *et al.,* (2017) studies on eight commercial cultivars like "Grand Naine (AAA), Robusta (AAA), Martaman (AAB), Champa (AAB), Kanthali clone-1 (ABB), BagdaKanthali (ABB), BaishChhara (ABB), and Behula (ABB)" were effectively induced by macro-propagation technology for large number of healthy planting materials. The AAA group had higher primary roots (2.20-2.65/plantlet) than the AAB and ABB groups (1.23 to 2.29/plantlet) two weeks following treatment. Grand Naine had the largely primary and secondary roots (10.80/plant) and BaishChhara had the least (9.20/plant) after hardening.

2.10. Effects of different growing media on number of secondary roots

Samanta *et al*., (2016) studies that, standardization of macro-propagation in banana cultivars with different treatments were taken i.e. "T_1 [Sawdust + VAM (30g]), T_2 [Sawdust + *Trichoderma viride* (30g)], T_3 [Sawdust + VAM (30g) + *Trichoderma viride* (30g]), T_4 [Sawdust + IBA (dipping in 0.25% solution) + Azospirillum (30g]), T_5 [Sawdust + BAP (4ml) + *Bacillus subtilis (*30g]), T_6 [Sawdust + VAM (30g) + BAP (4ml) + *Bacillus subtilis (*30g]), along with a control as T_7". The result of investigation is treatment, Sawdust with VAM (30g), BAP (4ml) and *Bacillus subtilis* (30g). Among the cultivars assessed, Bantala produced the most secondary roots (12.64) when treated Sawdust with VAM (30g), BAP (4ml) & Bacillus subtilis (30g).

Thungon *et al.,* (2015) stated that, number of roots, length of roots, secondary roots were considerably higher in T2 (*Trichoderma viride*), T3 (*Azospirillum* + PSB) and T4 (BAP) treatment. Higher number of secondary roots, longer roots with greater girth, higher number of leaves (5.80), and roots (25.16) might be the result of

inoculation of plant growth promoting bacteria that stimulated the root growth and development.

Sannigrahi *et al*., (2017) studies on eight commercial cultivars like "Grand Naine (AAA), Robusta (AAA), Martaman (AAB), Champa (AAB), Kanthali clone-1 (ABB), BagdaKanthali (ABB), BaishChhara (ABB), and Behula (ABB)" were effectively induced by macro-propagation technology for large number of healthy planting materials. Grand Nain had the more number of secondary roots (35.50/plant) and BaishChhara had the least (31.60/plant) after hardening.

2.11. Effects of different growing media on root length

Samanta *et al*., (2016) studies that, standardization of macro-propagation in banana cultivars with seven treatments were taken i.e. "T_1 [Sawdust + VAM (30g]), T_2 [Sawdust + *Trichoderma viride* (30g)], T_3 [Sawdust + VAM (30g) + *Trichoderma viride* (30g]), T_4 [Sawdust + IBA (dipping in 0.25% solution) + Azospirillum (30g]), T_5 [Sawdust + BAP (4ml) + *Bacillus subtilis (*30g]), T_6 [Sawdust + VAM (30g) + BAP (4ml) + *Bacillus subtilis (*30g]), along with a control as T_7". Treatment with Sawdust with VAM (30g), BAP (4ml) & *Bacillus subtilis* is the result of the investigation (30g). Among the cultivars tested, Bantala produced the longest root length (6.44 cm) when treated with Sawdust with VAM (30g), BAP (4ml) & *Bacillus subtilis* (30g).

Poldma *et al*., (2005) investigated the effect of a rhiozosphere competent biocontrol agent – Under greenhouse circumstances, the effects of *Trichoderma viridae* on the growth and yield of lettuce plants (*Lactuca sativa*). *Trichoderma*-treated lettuce plants had 43 percent longer roots than control lettuce plants, but the average diameter of the roots was smaller.

Shanamugaih *et al*., (2009) noticed that among several bio fertilizer used like, *T. viride* and *P. fluroescens*. Among the bio fertilisers tested, *Trichoderma viride* was shown to be more effective than *Pseudomonas fluroescens*. Seed germination percent, root length, shoot length, fresh weight, dry weight, and vigour index were all significantly improved by *T. viride* and *P. fluroescens*. *T. viride*-infected cotton plants developed 2.7 and 2.4 times longer shoot and roots, while *P. fluorescens* grew 2 and 1.8 times longer shoots and roots. Pre-treated cotton seeds by *T. viride* showed 4 and 3.1 fold shoot and root length elongation, respectively, as compared to the control,

and pre-treated cotton seeds by *P. fluorescens* showed 3.1 and 2.8 fold shoot and root length elongation.

Al-Amin *et al.* (2009) reported that, different concentrations of BAP on virus-free plant regeneration, shoot multiplication, and varied concentrations of IBA were employed at 10, 20, and 30 DAI. The longest lengths (2.93, 4.63, and 5.88 cm) were reported in the same treatment at 10, 20, and 30 DAI, which was statistically significant.

2.12. Benefit cost ratio

Singh *et al*., (2003) carried out to a study to know the impact of a mycorrhizal bio-fertilizer inoculation combined with a lower dose of chemical fertilizers on banana yield and profitability. With an output/input ratio of 2.05 and a benefit cost ratio of 1.05. The economics of banana production when inorganic fertilisers and mycorrhizal bio-fertilizers were combined indicated yield optimization at VAM + N + 1/2P + K. As a result, the recommended amount of NPK was required for yield maximization, but the best yield may be achieved with a 50% reduction in phosphorus fertilizer.

Vasane *et al*., (2006) investigated how to improve the secondary hardening of banana plantlets (*Musa paradisiaca* var Grand naine). The usage of VAM (for growth) such as *Glomus intraradices*, as well as potting media such as soil:pressmud (3:1), demonstrated that potting media is both cost efficient and environmentally benign, and that VAM aids in the growth of banana plantlets.

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CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

An experiment entitled "Studies on Macro-propagation of Banana (*Musa* spp.)" was carried out during 2020-2021. The detailed account of materials used and methods adopted during the investigation are embodied in this chapter.

3.1. Experimental site

The experiment entitled "Studies on Macro-propagation of Banana (*Musa* spp.)" was conducted at All India Co-ordinated Research Project on for Fruit crops research field, Department of Horticulture. Dr. Rajendra Prasad Central Agriculture University, Pusa, Samastipur (Bihar) 848125 during the year 2020-2021.

3.2. Meteorological condition

Dr. Rajendra Prasad Central Agriculture University, Pusa Farm, is situated in the Samastipur district of north Bihar on the Southern-Western bank of the river Burhi Gandhak at 25º59' North latitude and 85º48' East longitude with an altitude of 52.92 meters above the mean sea level. There are sub-tropical and sub-humid monsoon climates here. The average rainfall in this area is 1270 mm, with nearly 80-90 percent of that falling between June and November during the South-West monsoon. The scorching weather started in early March and lasted until the end of May. Temperatures typically begin to drop in the second fortnight of October and reach their lowest point in the early months of January. It begins to rise again around the end of February and reaches its peak in May-June. In May, the temperature rises to 42°C, with 81 percent of normal humidity at 7 a.m.

3.3. Weather condition during crop season

During the crop growing season, the weather data concerning maximum and minimum temperature, rainfall, and relative humidity were obtained from the Agrometeorology section, RPCAU, Pusa. The meteorological data from November 2020 to June 2021 are presented in Appendix-1.

3.4. Experimental material

3.4.1. Experimental details

Name of the crop: Banana

Name of variety: Grand Naine (AAA) & Alpan (AAB)

Year of study: 2020-2021

Experimental design: Two-factors Completely Randomized Design (CRD)

Number of replications: 5

Number of treatment: 8

Experimental material: Suckers

Total number of corm per treatment - 20

Total number of corm - 320

3.4.2. Experimental design

The material under study was constituted of sword suckers of healthy mother plants and the experiment was laid out in two factors Completely Randomized Design (CRD) with 8 treatments and 5 replication of using different growing media as sawdust, banana fiber waste, cocopeat, and different type of biofertilizer as *Azotobacter*, & *Trichoderma* combination of each other.

3.4.3. Treatment details

T_1: Sawdust

T_2: Sawdust + *Azotobacter*

T_3: Sawdust + *Trichoderma*

T_4: Sawdust + *Azotobacter* + *Trichoderma*

T_5: Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*

T_6: Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*

T_7: Sawdust (50%) + Cocopeat (50%) + *Azotobacter*

T_8: Sawdust (50%) + Cocopeat (50%) + *Trichoderma*

3.5. Growing media

The sawdust substrate used as common in treatment (T_1 to T_4) and treatment (T_5 and T_6) mixed with 50% sawdust and 50% banana fibre waste and treatment (T_7 and T_8) mixed with 50% sawdust and 50% cocopeat and using a different type of biofertilizer like *Azotobacter* common using in treatment (T_2, T_4, T_5, and T_7) and

Trichoderma common using in treatment (T_3, T_4, T_6, and T_8) combination as propagation media.

3.6. Preparation of bed

The bed size is 2×1 meter and depth having 30 cm and after preparation of bed filled with different growing media like sawdust, banana fibre waste, and cocopeat up to the 15 cm height.

3.7. Selection of material

Healthy suckers, selected from healthy mother plant as well as diseases and pest-free sucker.

3.8. Preparation of growth substance solution

3.8.1. Benzyl amino purine (BAP)

To prepare the solution, 40 mg BAP for one liter of water was taken. Dissolved BAP in 95 percent absolute alcohol and the solution was made to 1000 ml by adding distilled water than 4 ml prepared solution for recommended treatment was used in the experiment.

3.9. Preparation of corms

Corms of cultivars Grand Naine (AAA) and Alpan (AAB), weighing 1.0-1.5 kg, were obtained from the All India Co-ordinated Research Project on Fruit Crops, Dr. Rajendra Prasad Central Agriculture University, Pusa, and washed in running tap water for 15-20 minutes. The unsheathing leaf bases were cut from the pseudostem, and the top of the corm and aerial shoot were detopped.

To verify that the corm was free of nematodes and other root-borne/soil-borne diseases, the remainder of the pseudostem and roots were removed, and the exterior layer of the corm was scraped with a sharp knife. The apical meristem was removed from the rhizome to a depth of 2 cm, leaving a hollow in the rhizome with a diameter of 2 cm. Depending on the size of the sucker, the rest of the corm was given 4-6 crosscuts and incised up to 0.25-0.50 cm. Before planting, the corms were cleaned with 0.3 percent bavistin and air-dried in the shade for 3-4 hours to guarantee they were free of soil-borne illnesses.

3.10. Application of growth regulator solution

4-6 transverse incisions to a depth of 2 mm were made in the corms, and 30ppm BAP was poured into the cavity created by the ablation of the apical meristem. During the main and secondary stages of decapitation, the same therapy was used. To avoid direct sunlight, the suckers were completely covered with growth medium.

3.11. Application of bio-fertilizer

In this investigation, commercially available bio-fertilizers and plant growth hormones were employed as additions. At the primary and secondary decapitation phases, two different bio-fertilizer/bio-fungicides were applied alone or in combination to increase the bud proliferation rate. Before planting, 30 grammes of each bio-fertilizer were combined with the substrate.

3.12. Planting procedure of suckers

The bed size is 2×1 meter and depth having 30 cm. Decapitated corms was planted individually in a bed filled with sawdust, banana fibre waste, and cocopeat leaving 5cm from the top. Corms were buried 5 cm deep in the substrate, with treatments applied and growth medium applied up to a height of 2 cm. The sprouting shoots were allowed to develop for 25-30 days after primary decortication, and when they reached the three-leaf stage (height 15-20 cm, stem girth 2.5 cm), secondary decapitation was applied. The plantlet's aerial part was beheaded, the juvenile meristem was removed, and the young rhizome was given 4-6 horizontal incisions and coated with sawdust. Secondary and tertiary decapitations were done in the same way. The corm was carefully taken from the substrate and cleaned toward the conclusion of the tertiary bud stage. Each plantlet was separated to retain at least 2-3 ramified roots. The separated plantlets were Red soil:Sand: Farmyard manure (1:1:1) filled in poly bags with drainage holes. Plantlets were watered sufficiently and maintained under shade for 45 days.

3.13. Observation recorded

3.13.1. Survival percentage

The final survival of rhizomes was recorded out of total rhizomes that survived after transplanting and expressed in percentage. The total number of rhizomes that survived after transplanting in beds was counted as survival rhizomes

per treatment. The total number of rhizomes considered as the number of rhizomes per treatment success percentage.

$$\text{Survival percentage} = \frac{\text{Number of rhizome survival}}{\text{Total number of rhizome}} \times 100$$

3.13.2. Days taken for primary bud emergence

Decapitated rhizomes were transplanted in different growing media and primary buds emerged after few days of transplanting. The time it took to grow the first bud to last bud after rhizome transplantation was noted and expressed in days.

3.13.3. Number of primary shoots

Decapitated rhizomes were transplanted in different growing media and primary buds emerged after few days of transplanting. They were counted day by day and it is expressed in number.

3.13.4. Days taken for secondary bud emergence

Primary buds attend 2-3 leaf stage and 25-30 cm height they were ready for secondary decapitation. Secondary buds have emergence few days after secondary decapitation. The time it took to grow the first bud to last bud after secondary decapitation was noted and expressed in days.

3.13.5. Number of secondary shoots

Secondary shoots counted after emerged secondary shoots and they were counted and expressed in number.

3.13.6. Days taken for tertiary bud emergence

Secondary buds attend 2-3 leaf stage and 25-30 cm height. They were ready for tertiary decapitation. The time it took to grow the first bud to last bud after tertiary decapitation was counted and expressed in days.

3.13.7. Number of tertiary shoots

Tertiary shoots counted after emerged tertiary shoots and they were counted and expressed in number.

3.13.8. Days taken for root emergence

Decapitated rhizomes were transplanted in different growing media and root emergence few days after transplanting. The time it took day by day to grow the first root initiation. The time taken to first root emergence after rhizome transplanting was recorded and expressed in days.

Step 1: Planting material

Step 2: Detopping and Washing

Step 3: Decapitated rhizome

Step 4: Decapitated rhizome with crosscut

Step 5: Transplanting

Step 6: Primary bud emergence

Step 7: Secondary bud emergence

Step 8: Tertiary bud emergence

Step 11: Plantlets

Step 10: Hardening

Plate No. 1: Steps of Macro-propagation Technique

3.13.9. Number of roots per shoot

The total number of roots per shoot was counted and was expressed in number.

3.13.10. Number of primary roots

After separate the tertiary shoots and transplanted in individually poly bags. After 45-60 days they were dig out and washed carefully by running water and counted primary roots. The number of primary roots was recorded and the mean was calculated. It was expressed in number.

3.13.11. Number of secondary roots

After separate the tertiary shoots and transplanted in individually poly bags. After 45-60 days they were dig out and washed carefully by running water and counted secondary roots. The number of secondary roots was recorded and the mean was calculated. It was expressed in number.

3.13.12. Number of tertiary roots

After separate the tertiary shoots and transplanted in individually poly bags. After 45-60 days they were dig out and washed carefully by running water and counted tertiary roots. The number of tertiary roots was recorded and the mean was calculated. It was expressed in number.

3.13.13. Root length (cm)

The roots of uprooted plantlets were washed. The length of the longest root was measured out in centimeter with the help of measuring tape and the length under each treatment was calculated.

3.13.14. Benefit cost ratio

This is showed the ratio of net profits to costs. Returns are expressed per invested rupees. This index measures the advantage that a farmer gains from the expenditures he spends on care.

Benefit: Cost ratio = Net return/ Cost of cultivation

3.14. Statistical analysis

Completely Randomised Design (two factors CRD) was used to analyze the data in this study, as advised by Snedecor and Cochran (1937). All the datas were statically analysed by using free web-based statistical analysis portal, OPSTAT developed by CCS Haryana Agricultural University, Hisar (http://14.139.232.166/opstat/). The critical difference (C.D.) was used to calculate the overall significance of differences among the treatments at a level of 5 %.

T_1: Sawdust

T_2: Sawdust + *Azotobacter*

T_3: Sawdust + *Trichoderma*

T_4: Sawdust + *Azotobacter* + *Trichoderma*

T_5: Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*

T_6: Sawdust (50%) + Banana fibre waste (50%) +

T_7: Sawdust (50%) + Cocopeat (50%) + *Azotobacter*

T_8: Sawdust (50%) + Cocopeat (50%) + *Trichoderma*

Plate No. 2: Representation photograph showing comparative performance in all treatments

T_1: Sawdust

T_2: Sawdust + *Azotobacter*

T_3: Sawdust + *Trichoderma*

T_4: Sawdust + *Azotobacter* + *Trichoderma*

T_5: Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*

T_6: Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*

T_7: Sawdust (50%) + Cocopeat (50%) + *Azotobacter*

T_8: Sawdust (50%) + Cocopeat (50%) + *Trichoderma*

Plate No. 3: Effect of different growing media on root lengt

CHAPTER - IV

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

An experiment was taken up in the present study entitled 'Studies on Macro-propagation of Banana (*Musa spp*.)' targeting the standardization and validation of macro-propagation technique for banana. Besides, the best-suited substrate media was identified for the macro-propagation technique. The results of the experiment are comprehensively being presented here.

4.1. Survival percentage

There were significant differences among the performance of different growing medias in terms of survival percentage of bananas cv. Grand Naine and Alpan (Table No. 1 & Fig. No. 1). The survival percentage ranged from 94.79 % in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 64.58 % in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments, but at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*), T_4 (Sawdust + *Azotobacter* + *Trichoderma*) and T_3 (Sawdust + *Trichoderma*). The survival percentage differed significantly across the varieties and comparatively higher survival percentage was recorded in cv. Grand Naine (85.42 %). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.2. Days taken for primary bud emergence

Significant differences were recorded among the performances of different growing medias in terms of days taken for the primary bud emergence in bananas cv. Grand Naine and Alpan (Table No. 2 & Fig. No. 2). The days taken for primary bud emergence ranged from 21.45 days in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 30.68 days in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments, which is at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*). The days taken for primary bud emergence differed significantly across the varieties and shorter duration was recorded in cv. Grand Naine (23.51 days). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.3. Number of primary shoots

The performances of different growing medias varied significantly in terms of the number of primary shoots for bananas cv. Grand Naine and Alpan (Table No. 3 & Fig. No. 3). The number of primary shoots ranged from 4.21 in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 1.48 in T_1 (Sawdust). The treatments, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments, but at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*) and T_4 (Sawdust + *Azotobacter* + *Trichoderma*). The number of primary shoots differed significantly across the varieties and comparatively higher number of primary shoots was recorded in cv. Grand Naine (3.21). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.4. Days taken for secondary bud emergence

There were significant differences among the performances of different growing medias in terms of days taken for the secondary bud emergence of bananas cv. Grand Naine and Alpan in macro-propagation technique (Table No. 4 & Fig. No. 4). The days taken for secondary bud emergence ranged from 46.91 days in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 56.06 days in T_1 (Sawdust). T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments, but at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*), T_4 (Sawdust + *Azotobacter* + *Trichoderma*) and T_3 (Sawdust + *Trichoderma*). The days taken for secondary bud emergence differed significantly across the varieties and comparatively shorter duration was recorded in cv. Grand Naine (49.76 days). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.5. Number of secondary shoots

Different growing medias significantly regulated the number of secondary shoots in bananas cv. Grand Naine and Alpan in macro-propagation technique and the data is presented in Table No. 5 & Fig. No. 5. The number of secondary shoots ranged from 7.16 in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 3.76 in T_1 (Sawdust). The treatments, T_6 (Sawdust (50%) + Banana fibre waste (50%) +

Trichoderma) was found to be statistically superior over all other treatments, but at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*), T_4 (Sawdust + *Azotobacter* + *Trichoderma*) and T_3 (Sawdust + *Trichoderma*). Across the varieties, the number of secondary shoots production differed significantly and comparatively higher number of secondary shoots was recorded in cv. Grand Naine (6.48). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.6. Days taken for tertiary bud emergence

Significant differences were recorded among the performances of different growing medias in terms of days taken for the tertiary bud emergence of bananas cv. Grand Naine and Alpan in the macro-propagation technique and the data is presented in Table No. 6 & Fig. No. 6. The days taken for tertiary bud emergence ranged from 58.99 days in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 83.71 days in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments, but at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*). The days taken for tertiary bud emergence differed significantly across the varieties. A comparatively shorter duration was recorded in cv. Grand Naine (66.69 days) for tertiary bud emergence across different growing medias. The interaction among the treatments and genotypes was statistically found to be non-significant.

4.7. Number of tertiary shoots

The performances of different growing medias differed significantly in terms of the number of tertiary shoots emergence in macro-propagation of bananas for cv. Grand Naine and Alpan. The data is presented in Table No. 7 & Fig. No. 7. The number of tertiary shoots ranged from 19.91 in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 13.20 in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be statistically superior over all other treatments, but at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*) and T_4 (Sawdust + *Azotobacter* + *Trichoderma*). The number of tertiary shoots differed significantly across the varieties and comparatively higher number of tertiary shoots was recorded in cv. Grand Naine

(19.21). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.8. Days taken for root emergence

The data presented in Table no. 8 & Fig. No. 8 inferred significant differences among the performance of different growing medias in terms of days taken for root emergence of bananas cv. Grand Naine and Alpan in macro-propagation technique. The days taken for root emergence ranged from 17.61 days in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 24.37 days in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments, which is at par with the which is T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*), T_4 (Sawdust + *Azotobacter* + *Trichoderma*), T_3 (Sawdust + *Trichoderma*) and T_2 (Sawdust + *Azotobacter*). The days taken for root emergence differed significantly across the varieties. In comparison to the cv. Alpan, a shorter duration for root emergence was recorded in cv. Grand Naine (19.65 days). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.9. Number of roots per shoot

Significant differences were observed among the performances of different growing medias in terms of the number of roots per shoot of macro-propagation of bananas cv. Grand Naine and Alpan and the data is presented in Table No. 9 & Fig. No. 9. The number of roots per shoot ranged from 161.10 in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 96.08 in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be statistically superior over all other treatments, which is at par to the treatment T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*). The number of roots per shoot differed significantly across the varieties and comparatively higher number of roots per shoot was recorded in cv. Grand Naine (130.83). The interaction among the treatments and genotypes was statistically recorded to be non-significant.

4.10. Number of primary roots

The performance of different growing medias tested for macro-propagation of bananas differed significantly in terms of the number of primary roots emerged for bananas cv. Grand Naine and Alpan in macro-propagation technique. The data is

presented in Table No. 10 & Fig. No. 10. The number of primary roots ranged from 24.89 in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 11.03 in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments, but at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*). The number of primary roots differed significantly across the varieties and comparatively higher number of primary roots was recorded in cv. Grand Naine (18.74). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.11. Number of secondary roots

The observations presented in the Table No 11 & Fig. No. 11, indicated significant differences among the performances of different growing medias in terms of the number of secondary roots of bananas cv. Grand Naine and Alpan . In the macro-propagation experiment, the number of secondary roots ranged from 46.32 in the treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 24.04 in treatment, T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments, but at par with the T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*). The number of secondary roots emerged differed significantly across the varieties and comparatively higher number of secondary roots was recorded in cv. Grand Naine (37.13). The interaction among the treatments and varieties was statistically found to be non-significant.

4.12. Number of tertiary roots

Significant differences were observed among the performance of different growing medias in terms of the number of tertiary roots of bananas cv. Grand Naine and Alpan. The data generated from the macro-propagation experiment is presented in Table No. 12 & Fig. No. 12. The number of tertiary roots ranged from 89.90 in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 61.01 in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be significantly superior over all other treatments. The number of tertiary roots differed significantly across the varieties and comparatively higher number of secondary roots was recorded in cv. Grand Naine (74.97). The

interaction among the treatments and genotypes was statistically found to be non-significant.

4.13. Root length (cm)

The observations pertaining to root length of banana cv. Grand Naine and Alpan in the macro-propagation experiment is presented in the table no. 13 & fig. no. 13. It was inferred that, there were significant differences among the performance of different growing medias for modulating the root length. The root length ranged from 21.88 cm in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* to 6.44 cm in T_1 (Sawdust). The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* was found to be statistically superior over all other treatments, which is at par with the treatment T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*) and T_4 (Sawdust + *Azotobacter* + *Trichoderma*). The root length differed significantly across the varieties and comparatively higher root length was recorded in cv. Grand Naine (15.69 cm). The interaction among the treatments and genotypes was statistically found to be non-significant.

4.14. Benefit cost ratio

Among the eight treatments, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma)* recorded maximum net return and B:C ratio respectively (5977.25 and 2.99), followed by T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*) (5281.25 and 2.68), T_3 (Sawdust + *Trichoderma*) (4657.25 and 2.34 respectively) and T_4 (Sawdust + *Azotobacter* + *Trichoderma*) (4827.25 and 2.28 respectively) while lowest net return and B:C ratio was recorded in the treatment, T_1 (Sawdust) (3431.25 and 1.86 respectively). The data generated from the macro-propagation experiment is presented in Table No. 14 and *Appendix* 2.

Table No. -1 Effects of different growing media on survival percentage of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	66.67 (8.19)	58.33 (7.67)	64.58 (7.93)^{d}
T_2 (Sawdust + *Azotobacter*)	83.33 (9.16)	75.00 (8.72)	75.00 (8.94)^{bc}
T_3 (Sawdust + *Trichoderma*)	91.67 (9.61)	83.33 (9.16)	80.21 (9.38)^{ab}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	91.67 (9.61)	83.33 (9.16)	80.21 (9.38)^{ab}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	91.67 (9.61)	83.33 (9.16)	89.58 (9.38)^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	100 (10.05)	91.67 (9.61)	94.79 (9.83)^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	75.00 (8.72)	66.67 (8.19)	69.79 (8.46)^{cd}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	83.33 (9.16)	66.67 (8.19)	69.79 (8.68)^{bc}
Mean	85.42 (9.26)	76.04 (8.73)	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	0.30	0.15	0.42
CD	0.87	0.43	N/A

 # Values is parentheses are the transformed values, * Means followed by the same letter in a column are not significant

Table No. -2 Effects of different growing media on days taken for primary bud emergence of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	26.56	34.80	30.68^{e}
T_2 (Sawdust + *Azotobacter*)	23.78	31.68	27.73^{cd}
T_3 (Sawdust + *Trichoderma*)	23.44	30.81	27.13^{cd}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	21.99	29.11	25.55^{bc}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	20.91	26.15	23.53^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	19.92	22.97	21.45^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	25.88	32.89	29.39^{de}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	25.58	31.84	28.71^{de}
Mean	23.51	30.03	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	1.06	0.53	1.50
CD	3.06	1.53	N/A

*** Means followed by the same letter in a column are not significant**

Table No. – 3 Effects of different growing media on number of primary shoots of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	1.74	1.21	1.48^{e}
T_2 (Sawdust + *Azotobacter*)	2.93	1.74	2.34^{bc}
T_3 (Sawdust + *Trichoderma*)	3.23	1.92	2.57^{bc}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	3.89	2.45	3.17^{ab}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	4.43	3.29	3.86^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	4.84	3.58	4.21^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	2.15	1.36	1.76^{ce}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	2.46	1.55	2.00^{bc}
Mean	3.21	2.14	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	0.40	0.20	0.57
CD	1.17	0.59	N/A

*** Means followed by the same letter in a column are not significant**

Table No. – 4 Effects of different growing media on days taken for secondary bud emergence of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	54.85	57.27	56.06^{c}
T_2 (Sawdust + *Azotobacter*)	50.63	54.40	52.52^{bc}
T_3 (Sawdust + *Trichoderma*)	48.77	54.53	51.65^{ab}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	47.80	52.17	49.98^{ab}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	46.98	51.51	49.24^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	44.56	49.27	46.91^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	52.95	56.19	54.57^{bc}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	51.58	55.61	53.60^{bc}
Mean	49.76	53.87	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	1.88	0.94	2.66
CD	5.43	2.72	N/A

***Means followed by the same letter in a column are not significant**

Table No. – 5 Effects of different growing media on number of secondary shoots of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	4.70	2.81	3.76^{c}
T_2 (Sawdust + *Azotobacter*)	5.90	3.77	4.83^{bc}
T_3 (Sawdust + *Trichoderma*)	6.56	4.07	5.32^{ab}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	7.07	4.46	5.76^{ab}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	8.25	5.10	6.68^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	8.91	5.41	7.16^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	5.00	3.19	4.10^{bc}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	5.41	3.44	4.43^{bc}
Mean	6.48	4.03	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	0.67	0.34	0.95
CD	1.94	0.97	N/A

***Means followed by the same letter in a column are not significant**

Table No. – 6 Effects of different growing media on days taken for tertiary bud emergence of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	81.46	85.96	83.71^{e}
T_2 (Sawdust + *Azotobacter*)	65.87	79.25	72.56^{cd}
T_3 (Sawdust + *Trichoderma*)	63.84	77.18	70.51^{cd}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	62.96	72.78	67.87^{bc}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	59.37	67.23	63.30^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	55.40	62.58	58.99^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	74.76	83.25	79.01^{de}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	69.81	80.78	75.30^{de}
Mean	66.69	76.13	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	2.38	1.19	3.36
CD	6.88	3.44	N/A

***Means followed by the same letter in a column are not significant**

Table No. – 7 Effects of different growing media on number of tertiary shoots of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	16.25	10.15	13.20^{c}
T_2 (Sawdust + *Azotobacter*)	19.07	12.29	15.68^{bc}
T_3 (Sawdust + *Trichoderma*)	19.53	13.71	16.62^{bc}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	19.89	14.78	17.34^{ab}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	20.42	15.82	18.12^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	22.46	17.36	19.91^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	17.59	11.20	14.40^{bc}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	18.46	12.44	15.45^{bc}
Mean	19.21	13.47	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	0.94	0.47	1.33
CD	2.72	1.36	N/A

***Means followed by the same letter in a column are not significant**

Table No. – 8 Effects of different growing media on days taken for root emergence of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	22.37	26.36	24.37^{c}
T_2 (Sawdust + *Azotobacter*)	20.23	23.08	21.65^{ab}
T_3 (Sawdust + *Trichoderma*)	19.70	22.43	21.06^{ab}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	18.82	21.87	20.34^{ab}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	16.54	20.22	18.38^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	16.72	18.49	17.61^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	21.62	24.98	23.30^{bc}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	21.17	24.04	22.60^{bc}
Mean	19.65	22.68	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	1.47	0.73	2.08
CD	4.25	2.12	N/A

*** Means followed by the same letter in a column are not significant**

Table No. – 9 Effects of different growing media on number of roots per shoot of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	108.53	83.64	96.08^{f}
T_2 (Sawdust + *Azotobacter*)	118.99	109.19	114.09^{de}
T_3 (Sawdust + *Trichoderma*)	131.81	111.86	121.83^{cd}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	137.77	127.71	132.74^{bc}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	152.59	137.63	145.11^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	167.52	154.69	161.10^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	113.31	92.15	102.73^{ef}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	116.15	98.40	107.28^{de}
Mean	130.83	114.41	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	5.74	2.87	8.12
CD	16.62	8.31	N/A

***Means followed by the same letter in a column are not significant**

Table No. – 10 Effects of different growing media on number of primary roots of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	14.81	7.25	11.03^{d}
T_2 (Sawdust + *Azotobacter*)	15.93	13.46	14.70^{cd}
T_3 (Sawdust + *Trichoderma*)	16.84	14.22	15.53^{cd}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	19.93	15.55	17.74^{bc}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	22.58	19.25	20.91^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	25.54	24.24	24.89^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	18.16	9.96	14.06^{cd}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	16.10	12.24	14.17^{cd}
Mean	18.74	14.52	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	1.54	0.77	2.18
CD	4.47	2.23	N/A

***Means followed by the same letter in a column are not significant**

Table No. – 11 Effects of different growing media on number of secondary roots of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	28.80	19.29	24.04^{e}
T_2 (Sawdust + *Azotobacter*)	33.20	25.91	29.55^{cd}
T_3 (Sawdust + *Trichoderma*)	38.52	27.77	33.15^{cd}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	38.98	34.63	36.81^{bc}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	46.71	36.25	41.48^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	48.78	43.85	46.32^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	29.85	20.22	25.04^{de}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	32.16	20.96	26.56^{de}
Mean	37.13	28.61	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	2.58	1.29	3.65
CD	7.48	3.74	N/A

***Means followed by the same letter in a column are not significant**

Table No. – 12 Effects of different growing media on number of tertiary roots of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	64.92	57.10	61.01^{f}
T_2 (Sawdust + *Azotobacter*)	69.86	69.83	69.84^{de}
T_3 (Sawdust + *Trichoderma*)	76.45	69.87	73.16^{cd}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	78.86	77.52	78.19^{bc}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	83.30	82.14	82.72^{b}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	93.19	86.60	89.90^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	65.31	62.25	63.78^{ef}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	67.89	65.20	66.55^{ef}
Mean	74.97	71.31	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	2.19	1.09	3.09
CD	6.33	3.17	N/A

***Means followed by the same letter in a column are not significant**

Table No. – 13 Effects of different growing media on root length (cm) of banana in macro-propagation technique

Treatments	Genotypes		
	Grand Naine	**Alpan**	**Mean**
T_1 (Sawdust)	7.77	5.11	6.44^{e}
T_2 (Sawdust + *Azotobacter*)	14.44	9.26	11.85^{cd}
T_3 (Sawdust + *Trichoderma*)	15.73	12.29	14.01^{bc}
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	19.15	16.48	17.81^{ab}
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	20.53	18.89	19.71^{ab}
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	22.57	21.19	21.88^{a}
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	12.57	6.19	9.38^{de}
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	12.76	7.84	10.30^{cd}
Mean	15.69	12.16	
	Treatment	**Varieties**	**Treatment × Varieties**
SE(m)	1.53	0.76	2.16
CD	4.42	2.21	N/A

***Means followed by the same letter in a column are not significant**

Table No. 14. Benefit cost ratio of the macro-propagation technique

Treatments	Total number of plantlets per treatment	Gross Return (Rs.)	Total cost (Rs.)	Net return (Rs.)	B:C ratio
T_1 (Sawdust)	528	5280	1848.75	3431.25	1.86
T_2 (Sawdust + *Azotobacter*)	628	6280	1968.75	4311.25	2.18
T_3 (Sawdust + *Trichoderma*)	665	6650	1992.75	4657.25	2.34
T_4 (Sawdust + *Azotobacter* + *Trichoderma*)	694	6940	2112.75	4827.25	2.28
T_5 (Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*)	725	7250	1968.75	5281.25	2.68
T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*)	797	7970	1992.75	5977.25	2.99
T_7 (Sawdust (50%) + Cocopeat (50%) + *Azotobacter*)	576	5760	1988.75	3771.25	1.89
T_8 (Sawdust (50%) + Cocopeat (50%) + *Trichoderma*)	618	6180	2012.75	4167.25	2.07

CHAPTER - V

DISCUSSION

DISCUSSION

The present investigation, which was conducted to identify the best, suited growing media combination for the macro-propagation technique in banana. In view of this, the present study has been taken up with objective to find-out the best suited growing media and benefit cost ratio of the macro propagation technique for production of quality planting materials in banana cv. Grand Naine (AAA) & Alpan (AAB). The results obtained are discussed under different subheadings below in this chapter.

5.1. Survival percentage

In the initial stage of this mass multiplication method, the survival percentage of the corms depends on the aseptic practices from the very beginning stage. Diseases from the mother mat, corm weevil & other pest infestation may attribute the higher mortality of the corm. Since, for all the treatments uniform sterilization protocol was followed, a reasonably good survival percentage of corms were recorded for all the treatments. The survival percentage of banana corms in cv. Grand Naine and Alpan varied significantly with reference to different growing media. The growing media with sawdust (50%), in combination to banana fibre waste (50%) and *Trichoderma* performed superior over control and all other combinations. Which was at par to combination of medias viz. Sawdust (50%) mixture with banana fibre waste (50%) & *Azotobacter* followed by Sawdust in combination with *Azotobacter* & *Trichoderma* and sawdust with *Trichoderma*. Since, the media composed of banana fibre & sawdust (T_6) has a lower proportion of decomposed organic matters, the chances of secondary infection to the corms were minimal. This might attribute to a higher survival percentage of corms. Similar finding were reported by Esakkimuthu *et al.*, (2017) with treatments consisted of three growing media (FYM, Rice hull, Sawdust), two biofertilizers (*Azospirillum* and VAM) with sand alone as control. The proportion of plants that survived was greater in the treatments that employed FYM as a regeneration medium in conjunction with VAM.

Fig. No. 1. Effects of different growing media on survival percentage of banana in macro-propagation technique

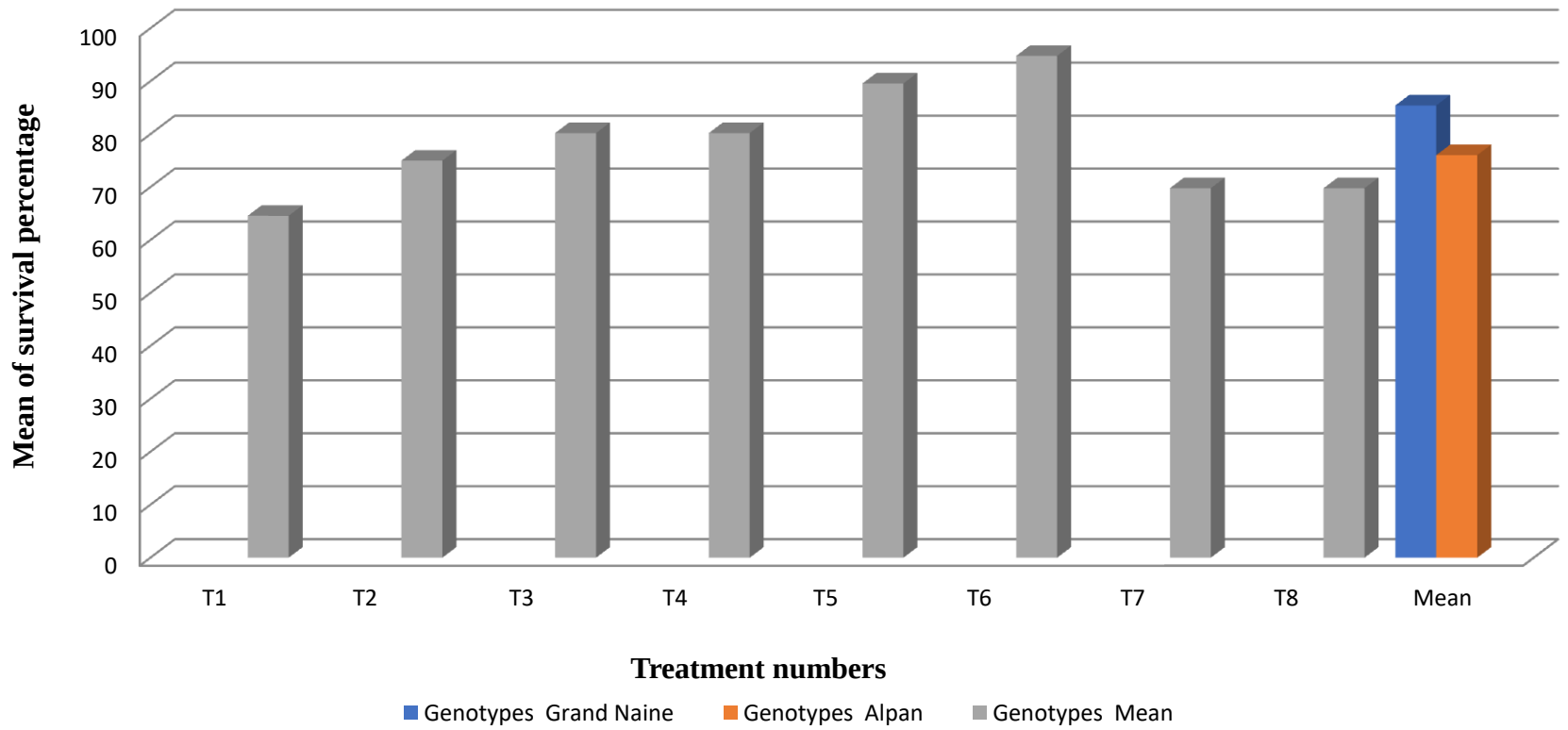
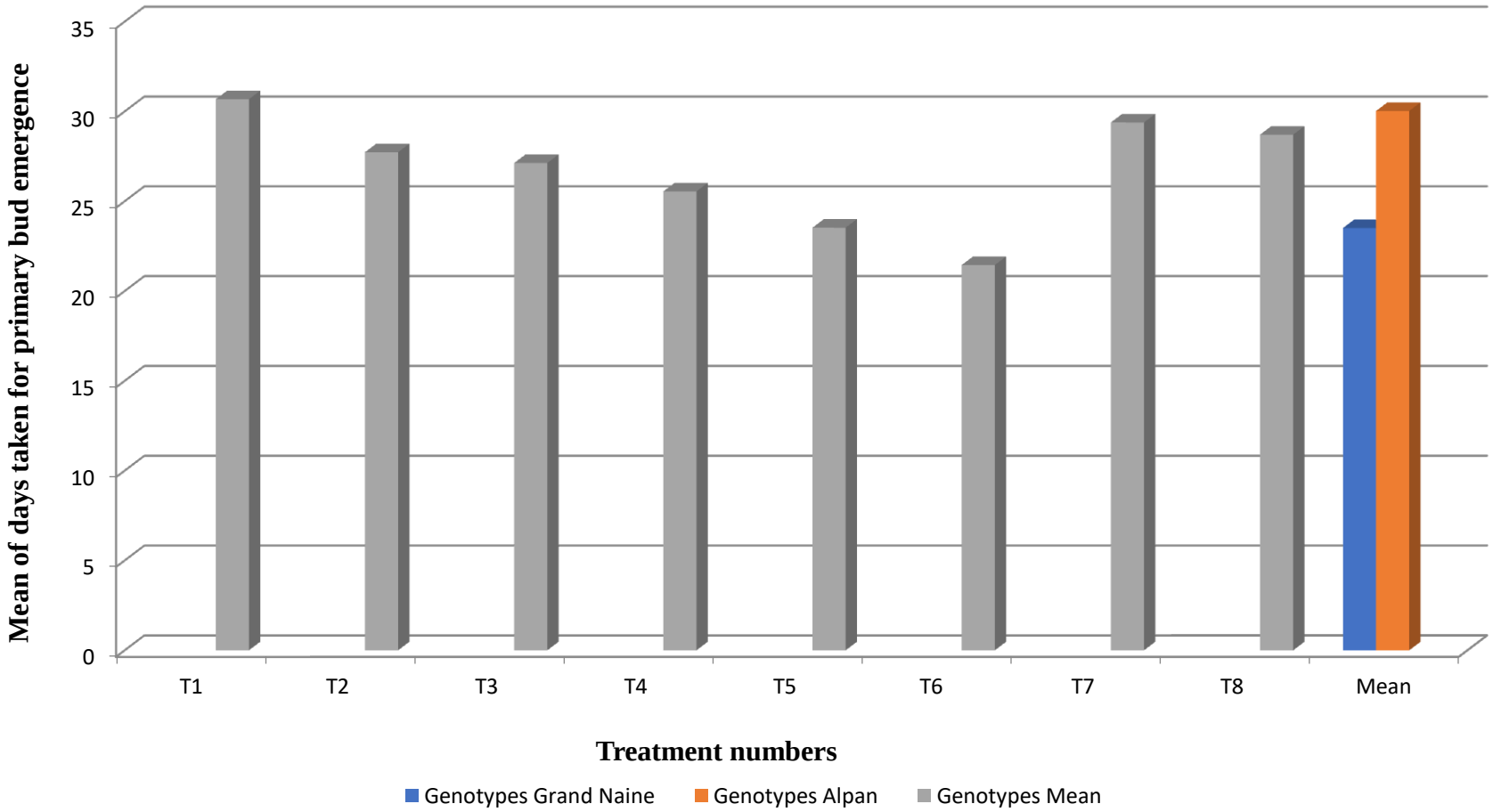


Fig. No. 2. Effects of different growing media on days taken for primary bud emergence of banana in macropropagation technique



5.2. Days taken for primary bud emergence

Decapitation of corms disrupts the apical dominance. This favored the emergence of numerous primary buds from the corms. Treatment of decapitated corms with BAP enhanced lateral bud proliferation in decapitation technique (Macias, 2001). The days taken for primary bud emergence differed significantly across the varieties and shorter duration was recorded mixture of sawdust (50%) with banana fibre waste (50%) and *Trichoderma* which was at par to media comprised of sawdust (50%), banana fibre waste (50%) & *Azotobacter*. Sajith *et al*., (2014) reported that treatment AMF and *Trichoderma viride* combination recorded the earliest bud regeneration in a short time of 28.3 days, followed by BAP + *Bacillus subtilis* in 29.70 days and AMF in 30 days. The same trend was observed for the rest of the treatments for the time taken for the bud initiation. Similar findings were reported by Sannigrahi *et al*., (2017), where the induction of primary shoots took 19.75 days in Grand Naine & 28.25 days in Bagda variety.

5.3. Number of primary shoots

The growing media, sawdust (50%) combined with banana fibre waste (50%) and *Trichoderma* was found to be significantly superior over all the treatments while, it was at par to growing media viz. combination of Sawdust (50%), banana fibre waste (50%) & *Azatobecter* and sawdust with *Azotobacter*, & *Trichoderma*. The maximum number of primary shoots was recorded in the cultivar Grand Naine (AAA). There were significant variations in genetic response of *Musa spp.* to suckering behavior in banana (Baiyeri and Aba, 2005). Hirimburegama & Gamage (1997), reported that banana with B-genome is of poor suckering behavior as compared to AAA group. This report corroborates the findings of our study. But in contrary, it was reported by Baiyeri & Aba (2005) that, bananas with B-genome had a higher suckering behavior. Probably such variations might be attributed to the genotypes & environmental interaction. A similar result was found by Sannigrahi *et al.*, (2017) that was effectively induced by macro-propagation technology for the large number of healthy planting materials. In the AAA group, the number of induced primary shoots was larger (3.23 to 3.40/rhizome), compared to the AAB (2.70-2.90 shoots/rhizome) and ABB (2.20-2.50 shoots/rhizome) groups.

Fig. No. 3. Effects of different growing media on number of primary shoots of banana in macro-propagation technique

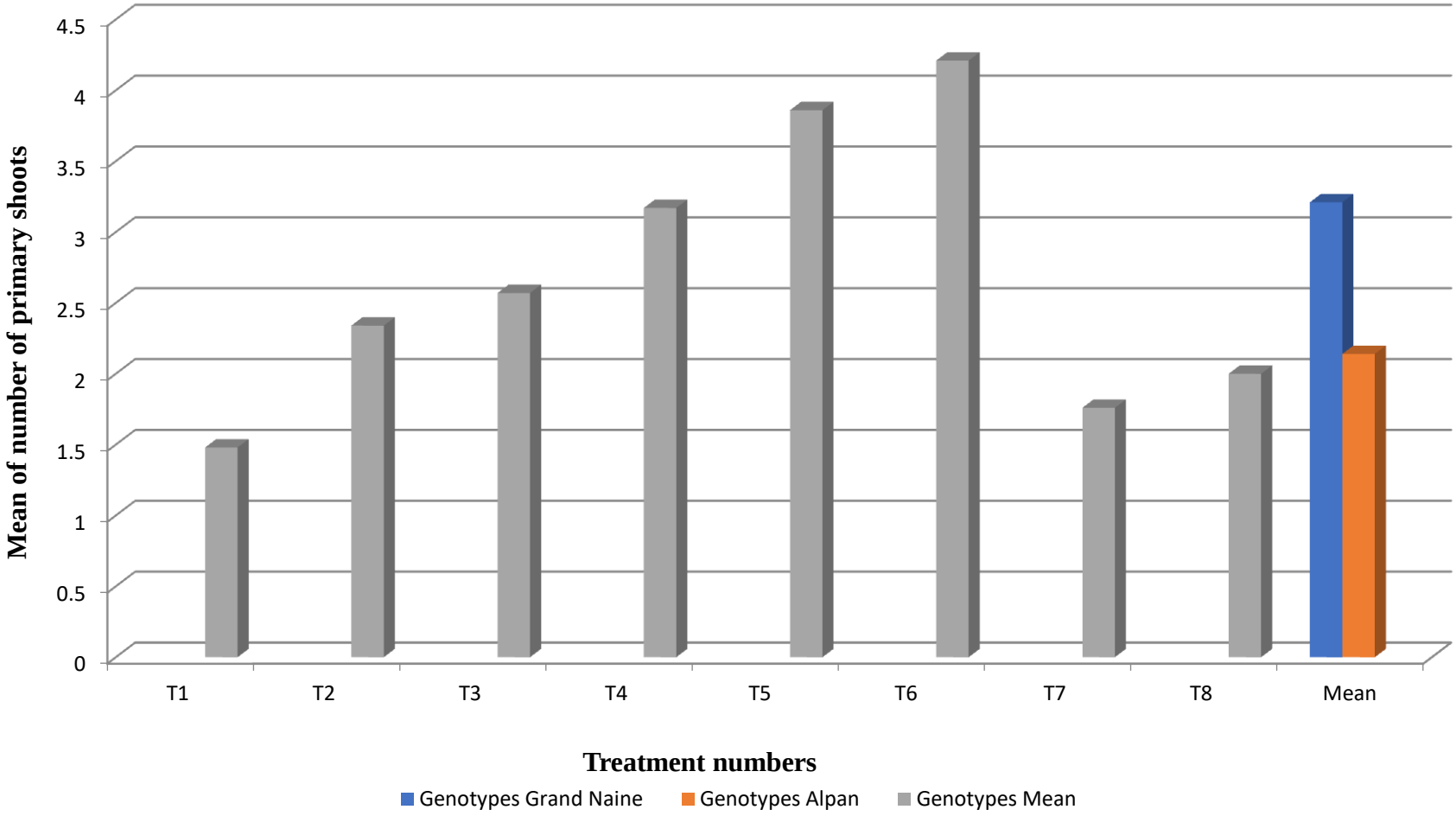
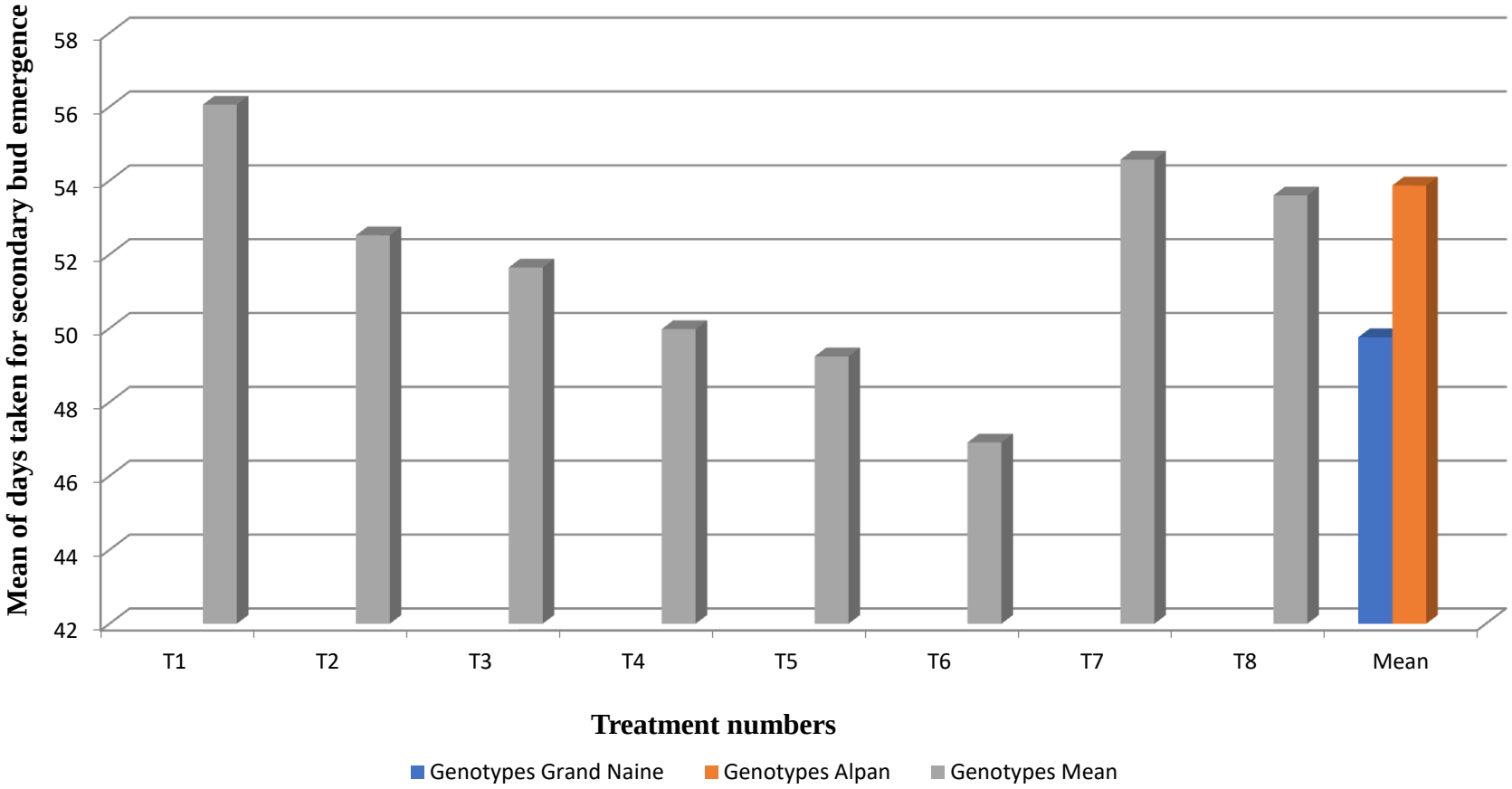


Fig. No. 4. Effects of different growing media on days taken for secondary bud emergence of banana in macro-propagation technique



5.4. Days taken for secondary bud emergence

Shorter duration was taken for secondary bud emergence in growing medium comprised of sawdust (50%), Banana fibre waste (50%) & *Trichoderma*. This was at par to media viz. combination of sawdust (50%) with, banana fibre waste (50%) & *Azotobacter*, and sawdust with *Azotobacter* & *Trichoderma*, and sawdust with *Trichoderma. B.subtilis* in combination with BAP and AMF alone or combination with *T. viride* increased the regeneration efficiency of secondary bud in cv. Bangladesh Malbhog as reported by Dayarani *et al*., (2013).

5.5. Number of secondary shoots

The performances of different growing medias varied significantly in terms of the number of secondary shoots for bananas cv. Grand Naine and Alpan. The medium comprised of sawdust (50%), banana fibre waste (50%) & *Trichoderma* was found to be statistically superior over all other treatments, and it was at par with the media combinations such as sawdust (50%), banana fibre waste (50%) & *Azotobacter* and media with sawdust, *Azotobacter* & *Trichoderma* and sawdust with *Trichoderma*. Pujar *et al*., (2017) standardized growing media (from earlier studies) *i.e*., the combination of Sawdust and FYM (1:1) BAP 40 ppm. Among different cultivars Grand Naine produced a significantly higher number of plantlets (15.02) after secondary decapitation. Similar results were also reported in wild bananas *Musa laterita* (Dayarani *et al*., 2013).

5.6. Days taken for tertiary bud emergence

A comparatively shorter duration was taken tertiary bud emergence which was recorded in the growing medium comprised of sawdust (50%), banana fibre waste (50%) & *Trichoderma.* At par value was recorded for the medium comprised of sawdust (50%), banana fibre waste (50%) & *Azotobacter*. In contrary to over findings Thungon *et al., (*2015) reported sawdust, paddy husks and cocopeat were used as three different growing media. The treatment combination of cocopeat and BAP (0.04%) could be recommended for the production of quality planting materials of ‘Malbhog’ banana through macro-propagation. Cocopeat had the quickest tertiary sucker separation (82.55 days).

Fig. No. 5. Effects of different growing media on number of secondary shoots of banana in macro-propagation technique

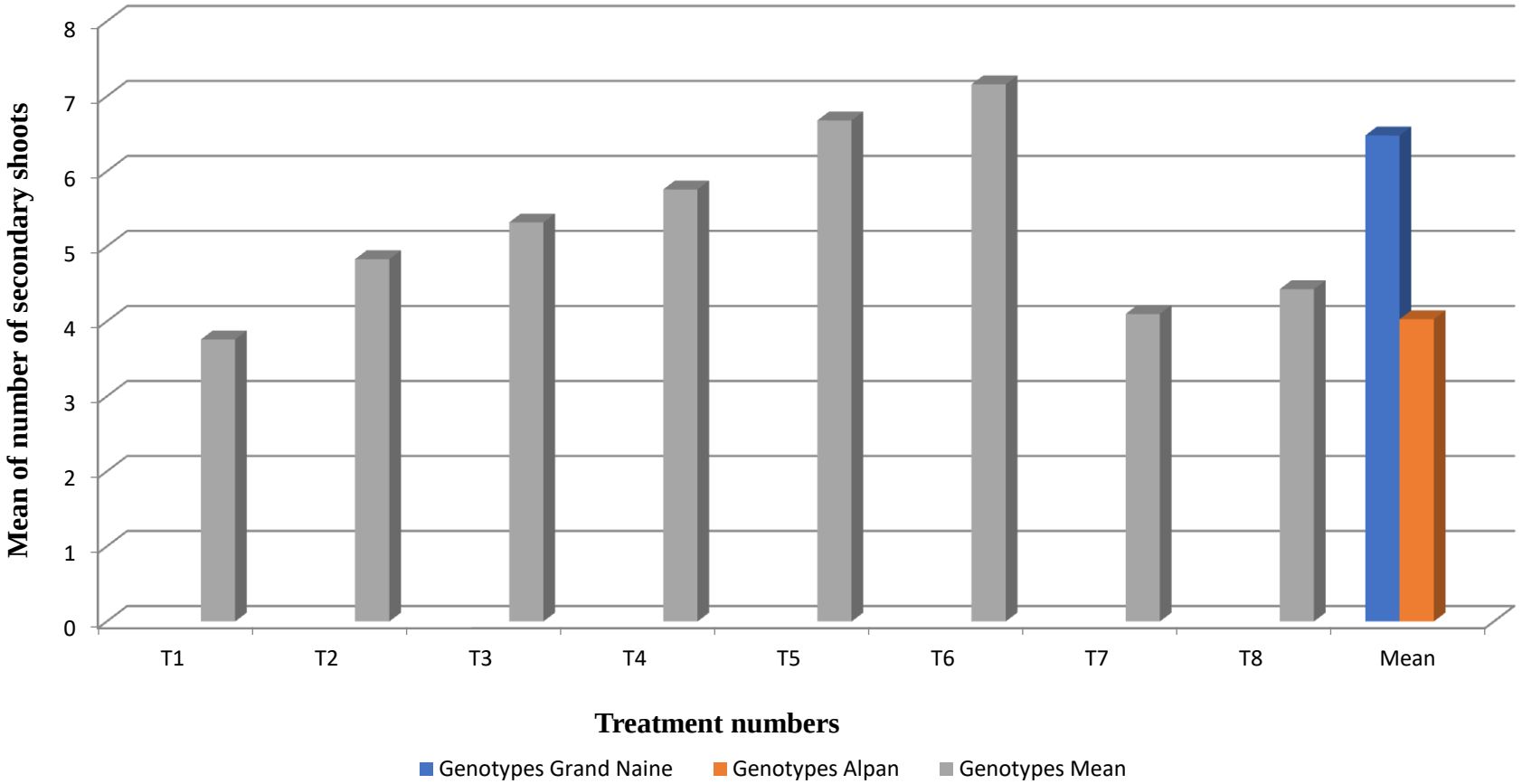
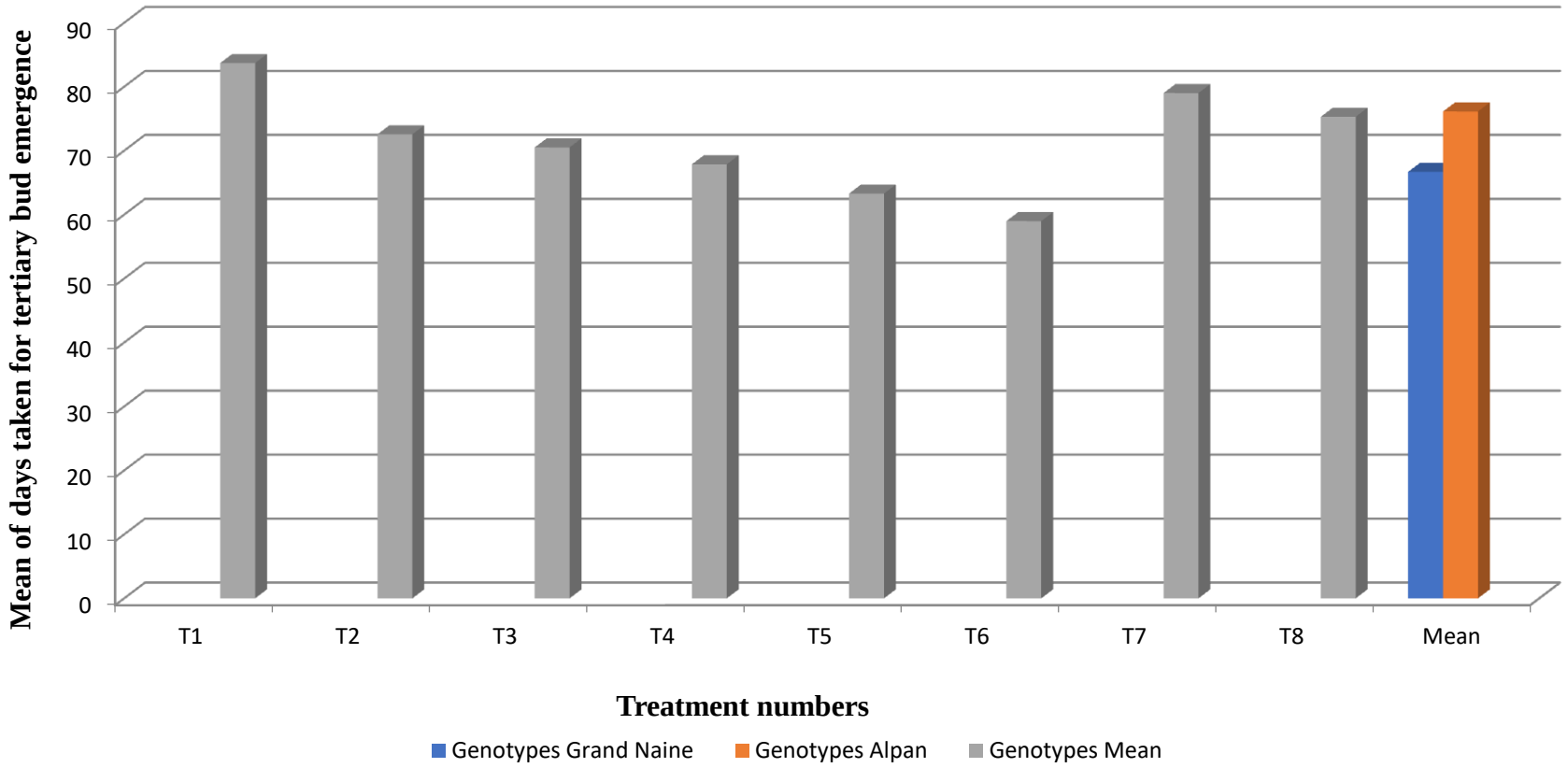


Fig. No. 6. Effects of different growing media on days taken for tertiary bud emergence of banana in macro-propagation technique



5.7. Number of tertiary shoots

Decapitation of secondary shoots favored tertiary bud proliferation. The number of tertiary shoots was recorded maximum in media comprised of sawdust (50%), banana fibre waste (50%) & *Trichoderma* and was found significantly superior over rest of the treatments, while the at par for the following medias, such as sawdust (50%), banana fibre waste (50%) & *Azotobacter* and sawdust, *Azotobacter,* & *Trichoderma* . Sannigrahi *et al.,* (2017) reported that healthy suckers (4-5 months old) were decapitated and pairing with rhizomes, which were planted in a growth media bed containing 2 kg sawdust with 30g *Trichoderma viride*/*Bacillus subtilis* & 30g VAM per corm and treated weekly with a 25 ppm 6-benzyl amino purine (BAP) solution. Result was found that the number of tertiary shoots produced per rhizome was highest in Grand Naine (24.23) and lowest in Kanthali (9.61).

5.8. Days taken for root emergence

For root emergence, lesser period was in cv. Grand Naine and in media combination of sawdust (50%), banana fibre waste (50%) & *Trichoderma)* followed by sawdust (50%), banana fibre waste (50%) & *Azotobacter* media sawdust, *Azotobacter* & *Trichoderma,* media sawdust & *Trichoderma* and media sawdust & *Azotobacter*. Similar kinds of results were obtained by Sannigrahi *et al.,* (2017) for induction of rooting in two weeks for macro-propagation technology in AAA group of bananas.

5.9. Number of roots per shoot

The media combination, sawdust (50%), banana fibre waste 50% & *Trichoderma* was recorded to be significantly superior other treatments, and was observed to be at par for the media combination of the sawdust (50%), banana fibre waste (50%) & *Azotobacter* in terms of maximum number of roots per shoots. Reports by Ali *et al*., (2011) and Ahmed *et al*., (2014) supported the results of the present study as they obtained the maximum number of roots.

Fig. No. 7. Effects of different growing media on number of tertiary shoots of banana in macro-propagation technique

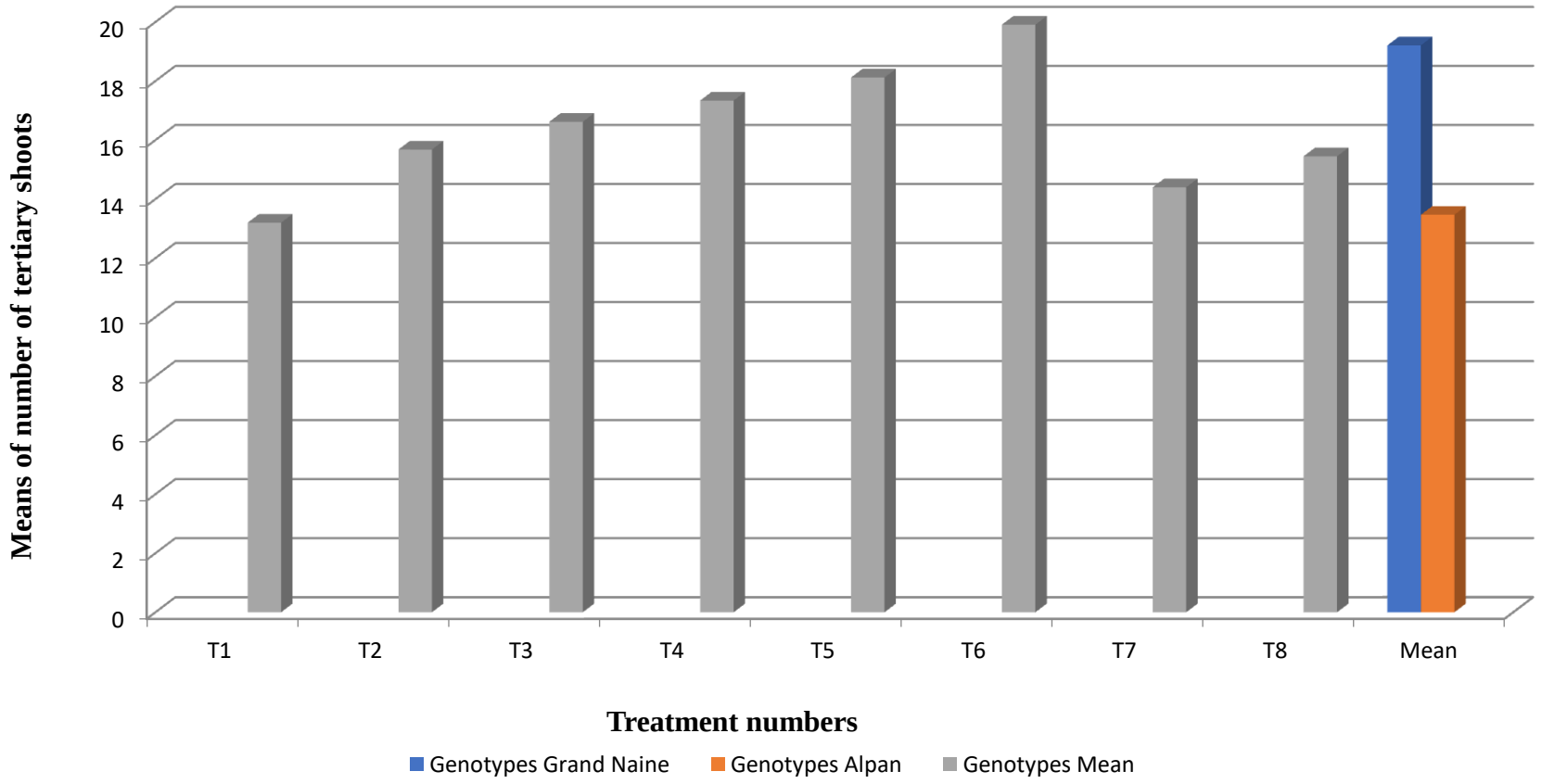


Fig. No. 8. Effects of different growing media on days taken for root emergence of banana in macro-propagation technique

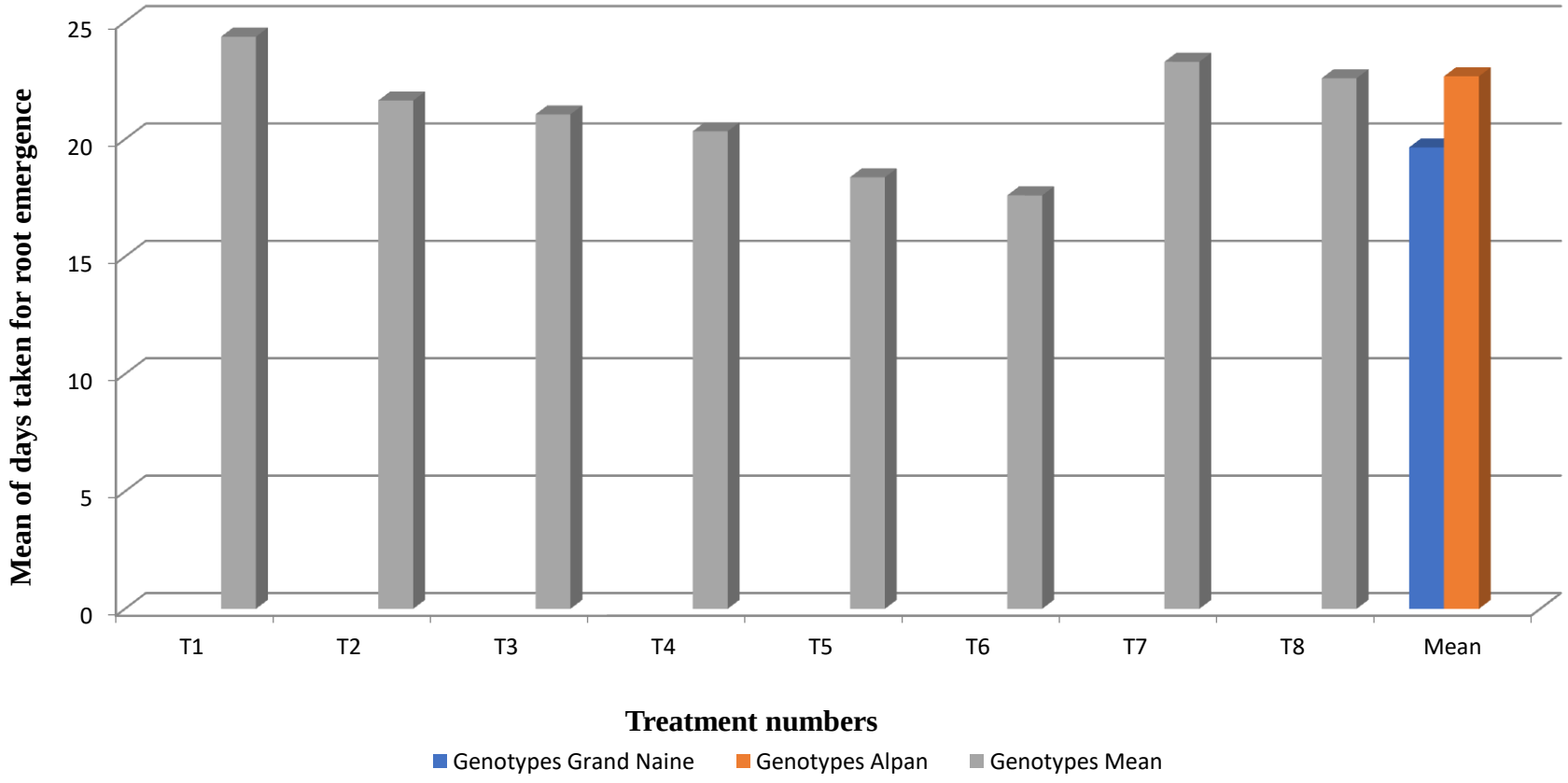
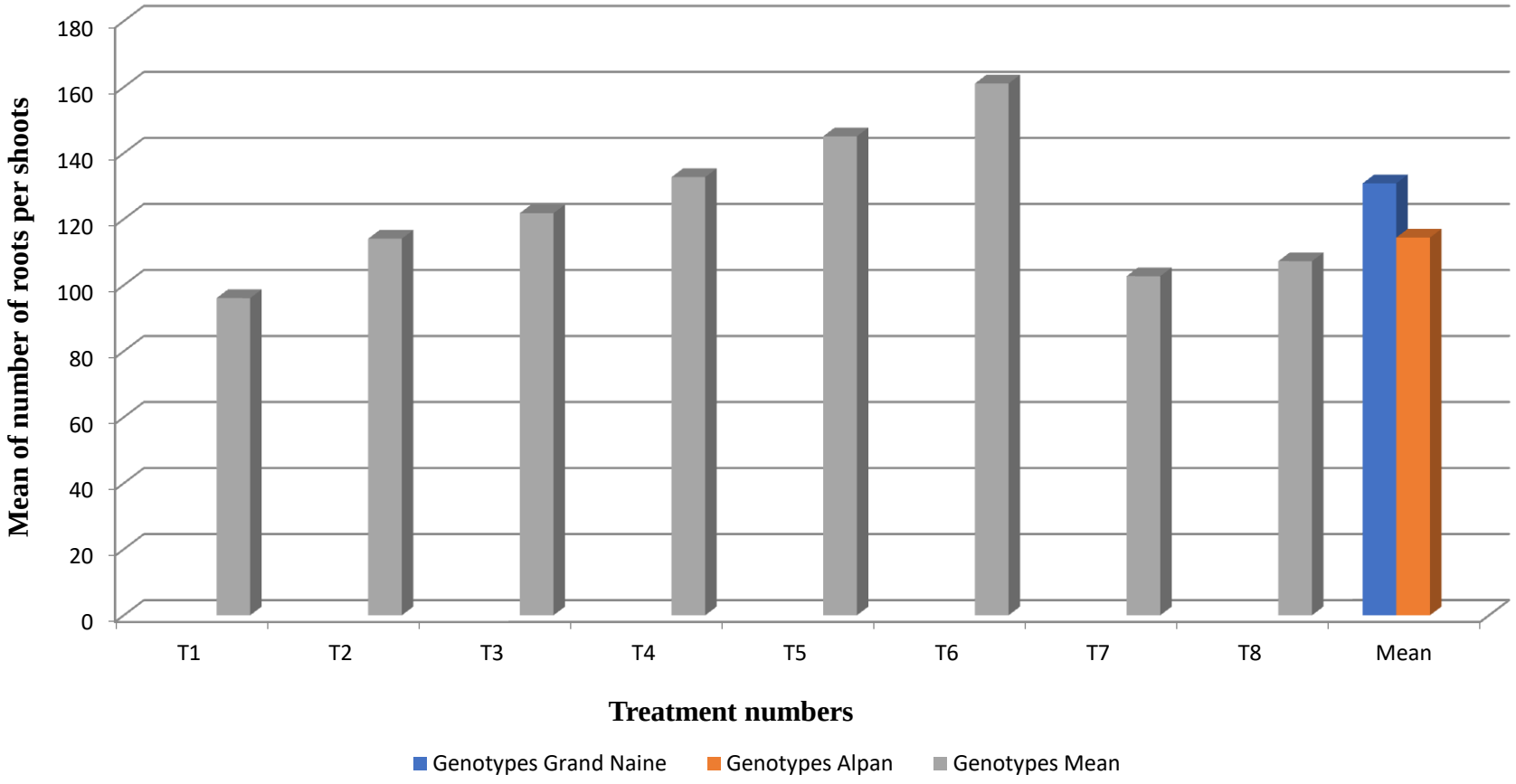


Fig. No. 9. Effects of different growing media on number of roots per shoot of banana in macro-propagation technique



5.10. Number of primary roots

The number of primary roots differed significantly across both the varieties studied and the maximum number of primary roots was recorded in cv. Grand Naine. Comparatively higher number of primary roots was recorded in growing media of sawdust (50%) & banana fibre waste (50%), & *Trichoderma* superior over all other treatments. This was at par to media combination sawdust (50%), banana fibre waste (50%) & Azotobacter. Sannigrahi *et al.,* (2017) reported that primary roots were induced two weeks after treatment in the AAA group, which were higher (2.20-2.65/plantlet) than the AAB and ABB groups (1.23 to 2.29/plantlet). After hardening, the number of primary and secondary roots was highest (10.80/plant) in Grand Naine and lowest in Baish Chhara (9.20/plant).

5.11. Number of secondary roots

The maximum number of secondary roots was recorded in media comprised of sawdust (50%), banana fibre waste (50%) & *Trichoderma* which was at par for the media combination sawdust (50%), & banana fibre waste (50%) & *Azotobacter*. Similar findings was reported by Thungon *et al.,* (2015) that number of roots, length of roots, secondary roots were considerably higher in T_2 (*Trichoderma viride*), T_3 (*Azospirillum* + PSB) and T_4 (BAP) treatment. The higher number of secondary roots, longer roots with greater girth, the higher number of leaves (5.80), and roots (25.16) might be the result of inoculation of plant growth-promoting bacteria that stimulated the root growth and development.

5.12. Number of tertiary roots

The number of tertiary roots noted in media combination sawdust (50%) with banana fibre waste (50%) & *Trichoderma* was found to be significantly superior over rest of the treatment. Reports by Ali *et al*. (2011) and Ahmed *et al*. (2014) support the results of the present study as they were noted that treatment with VAM and IBA showed a better root system.

Fig. No. 10. Effects of different growing media on number of primary roots of banana in macro-propagation technique

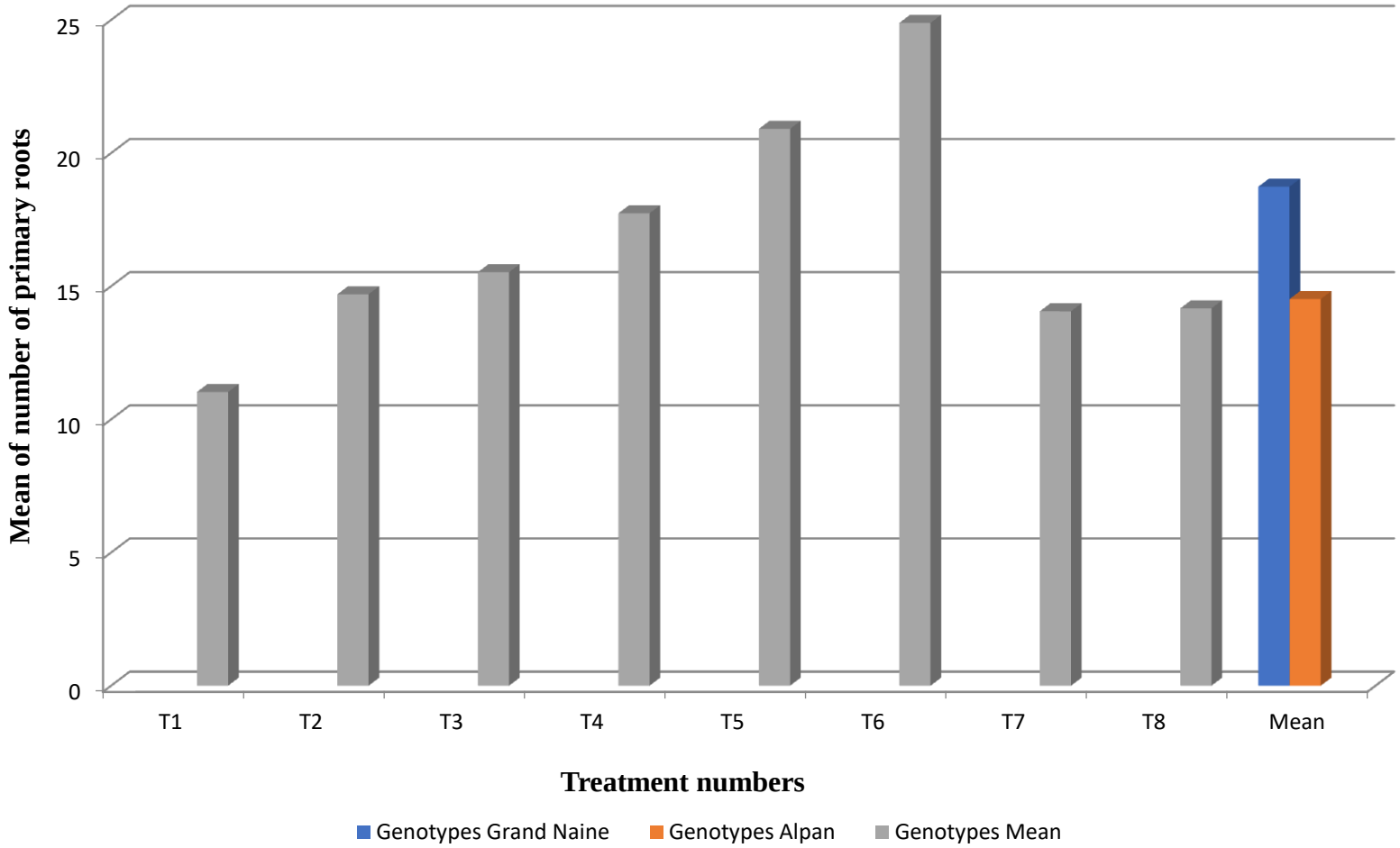


Fig. No. 11. Effects of different growing media on number of secondary roots of banana in macro-propagation technique

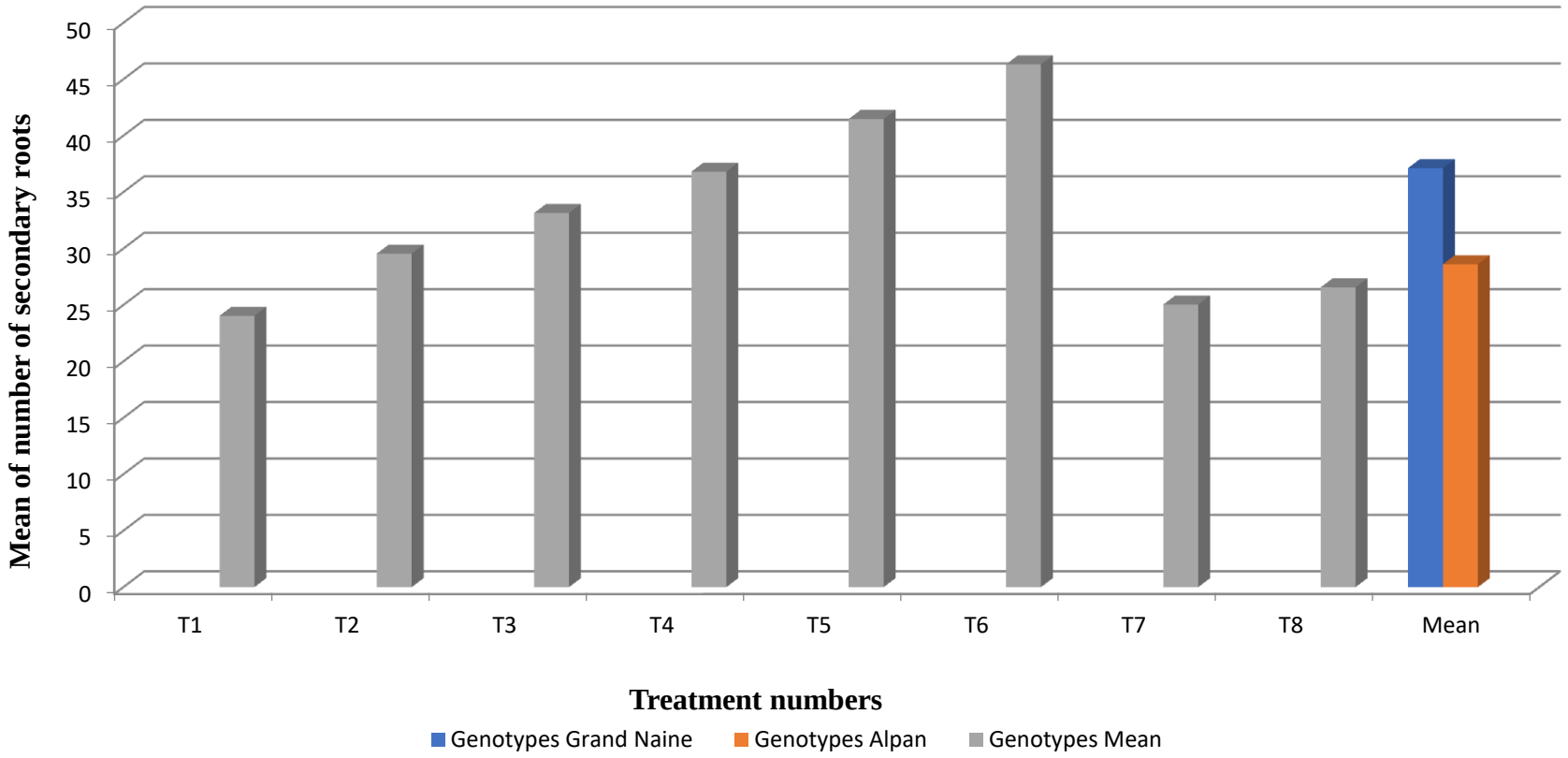
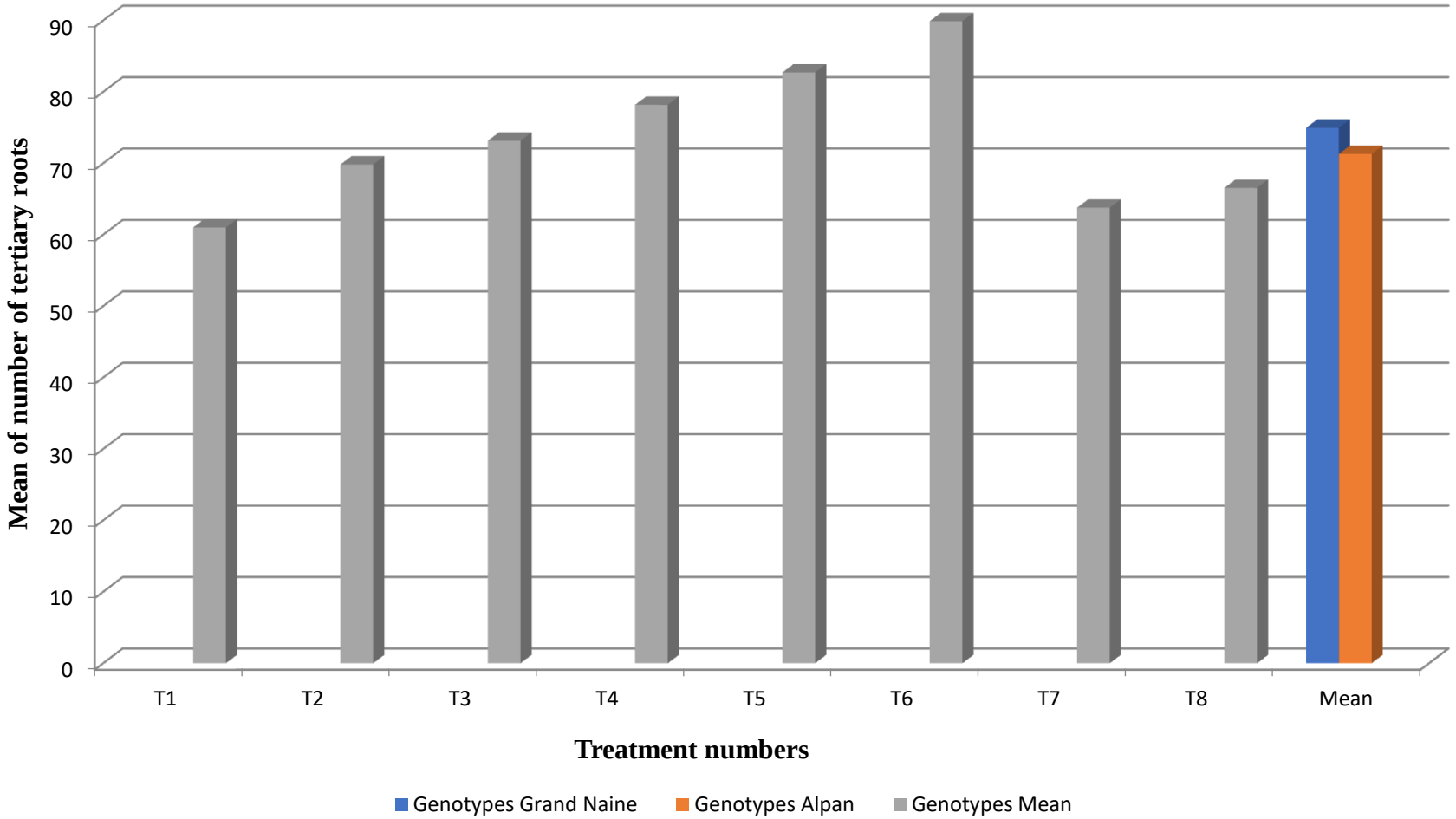


Fig. No. 12. Effects of different growing media on number of tertiary roots of banana in macropro-pagation technique



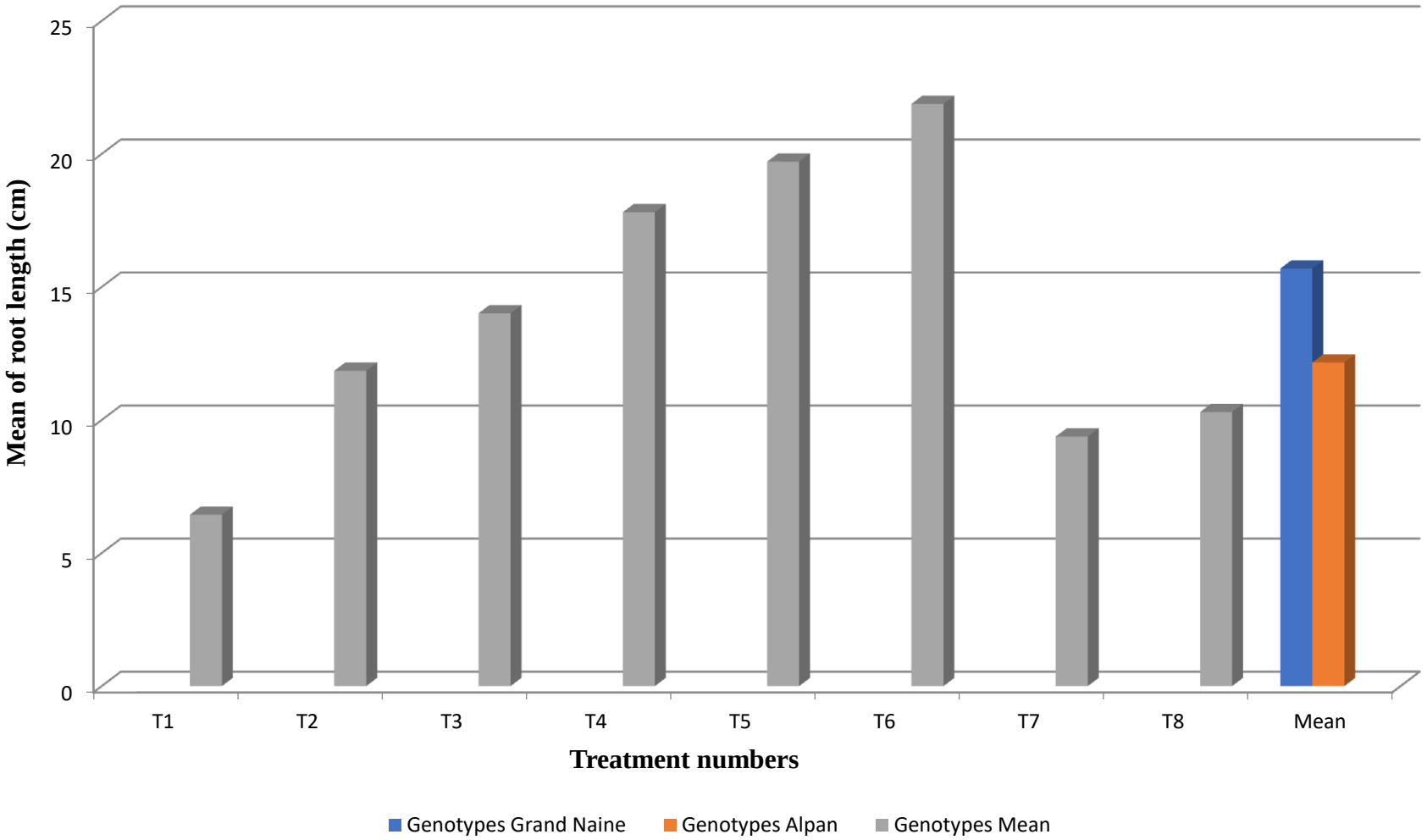
5.13. Root length (cm)

The maximum root length was recorded in media combination of sawdust (50%), banana fibre waste (50%) & *Trichoderma* was found to be significantly superior over rest of the treatments. For the following treatments viz. sawdust (50%), banana fibre waste (50%) & *Azotobacter* and media sawdust, *Azotobacter*, & *Trichoderma* at par value to the higher one was recorded. It might be due to the presence of microorganism VAM with *Bacillus subtilis* or *Trichoderma viride* which improves the physical composition of the growing medium is reported to have a profound effect on the supply of water, nutrient and air to the growing plantlets as well as known to affect anchorage nutrient and water holding capacity of the medium. This was in agreement with the finding of Sajith *et al.* (2014) and Baiyeri and Aba, (2005).

5.14. Benefit cost ratio

The maximum net return and B: C ratio was recorded in media sawdust (50%), banana fibre waste (50%) & *Trichoderma* followed by sawdust (50%) with mixture of banana fibre waste (50%) & *Azatobacter*. Similar result recorded by Singh *et al*. (2003) the economics of banana cultivation as affected by the combination of inorganic fertilizers and mycorrhizal bio-fertilizers showed yield optimization at VAM + N + 1/2P + K with output/input ratio of 2.05 and benefit cost ratio of 1.05. Thus, recommended dose of NPK was needed for yield maximization whereas optimum yield can be obtained with 50 % saving of phosphorus fertilizer.

Fig. No. 13. Effects of different growing media on root length (cm) of banana in macro-propagation technique



CHAPTER - VI

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present investigation entitled "Studies on Macro-propagation of Banana (*Musa* spp.)" was conducted at All India Co-ordinated Research Project on for Fruit crops research field, Department of Horticulture. Dr. Rajendra Prasad Central Agriculture University, Pusa, Samastipur (Bihar) 848125 during the year 2020-2021.

- Among the treatments tried in the experiment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*) proved to be best because the treatment recorded maximum survival percentage (94.79 %), and T_1 (Sawdust) recorded minimum survival percentage (64.58).
- The lowest number of days was taken for primary, secondary and tertiary bud emergence (21.45, 46.91 and 58.99 days, respectively). While maximum days were taken for primary (30.68 days), secondary (56.06 days), tertiary bud emergence recorded in the treatment, T_1 (Sawdust).
- The maximum number of primary (4.21), secondary (7.16) and tertiary shoots (19.91) was recorded in the treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*) and minimum number of primary, secondary and tertiary shoots was recorded in treatment, T_1 (Sawdust) (1.48, 3.76 and 13.20 with respectively).
- The days taken for root emergence (17.61 days) in the treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*) recorded minimum days and maximum days taken for root emergence (24.37) in the treatment, T_1 (Sawdust).
- The treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*) observed more number of roots per shoot (161.10). While in T_1 (Sawdust) recorded comparatively least number of roots per shoots (96.08).
- The number of primary, secondary and tertiary roots (24.89, 46.32 and 89.90 with respectively) comparatively maximum recorded in T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*) and the treatment, T_1 (Sawdust) recorded minimum number of primary (11.03), secondary (24.04) and tertiary roots (61.01).
- Among the treatments was recorded maximum root height (21.88 cm) in treatment, T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*) and T_1 (Sawdust) recorded lowest height recorded (6.44 cm).

From the result of an experiment conducted to study the, studies on macro-propagation of banana (*Musa* spp.).

- The macro-propagation technique is validated and hereby the best suited growing substrate and variety were identified in banana under the agro-climatic condition of north bihar.

- Among the growing substrates studied T_6 (Sawdust (50%) + Banana fibre waste (50%) + *Trichoderma*) was found to be superior in terms of Survival Percentage, Days Taken of Secondary Bud Emergence, Number of Primary, Secondary, and Tertiary Shoots and this at par to T_5(Sawdust (50%) + Banana fibre waste (50%) + *Azotobacter*) and T_4 (Sawdust + *Azotobacter* + *Trichoderma*).

- Between the varieties tested Grand Naine was observed to be more response than Alpan in terms of Survival Percentage, Days Taken of Primary, Secondary, and Tertiary Bud Emergence, Number of Primary, Secondary, and Tertiary Shoots.

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APPENDIX

Appendix-1

Monthly meteorological data during the experimental period (2020-2021)

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm)	Bright sunshine (hr.)
	Max.	Min.	Morning	Evening			
August -2020	33.1	24.7	91	82	154.8	2.5	6.6
September-2020	32.4	25.8	92	84	233.4	2.5	4.1
October-2020	33.1	24.3	88	70	_	2.8	6.9
November-2020	28.7	16.0	86	56	_	2.3	7.7
December-2020	22.5	10.2	95	71	_	0.9	3.3
January -2021	19.3	9.4	95	75	_	1.2	3.2
February-2021	26.0	12.0	91	63	_	2.0	7.4
March-2021	31.7	17.4	87	53	_	3.4	8.2
April-2021	35.8	19.7	79.3	39.1	0.8	5.4	8.1
May-2021	32.1	22.5	86.2	64.5	282.2	3.3	5.4

Appendix 2

S.No.	Particulars	Rate (Rs)	Quantity	Total cost (Rs)
1.	Sawdust	Rs. 5 per Kg.	240 Kg	1200
2.	Cocopeat	Rs. 6 per Kg.	40 Kg	240
3.	Banana fibre waste	Rs. 5 per Kg.	40 Kg	200
4.	*Azatobacter*	Rs. 100 per Kg	4800 g.	480
5.	*Trichoderma*	Rs. 120 per Kg	4800g	576
6.	Rhizome	Rs. 5 per rhizome	320	1600
7.	Total Labour	Rs. 365 per labour	30	10,950
8.	Other charges	-	-	640
9.	Price of 1 plantlets	Rs. 10		

- Total Plantlets – 5231
- Total Gross return – 52310
- Total cost – 15886
- Total Net Return – 36224
- Total B:C Ratio – 2.29