EVALUATION OF GROWTH AND YIELD PERFORMANCE OF *Cucurbita* spp. PLANTED AT DIFFERENT TIMES UNDER POPLAR BLOCK PLANTATION

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
in
FORESTRY
(Minor Subject: Vegetable Science)

By

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(L-2019-H-174-M)

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CERTIFICATE I

This is to certify that the thesis entitled "**Evaluation of growth and yield performance of *Cucurbita* spp. planted at different times under poplar block plantation**" submitted for the degree of M.Sc., in the subject of **Forestry** (Minor subject: **Vegetable Science**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Raziya Banoo (L- 2019-H-174-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

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

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CERTIFICATE – II

This is to certify that the thesis entitled, **"Evaluation of growth and yield performance of *Cucurbita* spp. planted at different times under poplar block plantation"** submitted by **Raziya Banoo (L- 2019-H-174-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.**, in the subject of **Forestry** (Minor subject: **Vegetable Science**) has been approved by the Student's Advisory Committee along with the External Examiner after an oral examination on the same.

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ABSTRACT

The present investigation entitled 'Evaluation of growth and yield performance of *Cucurbita* spp. planted at different times under poplar block plantation' was carried out at the experimental area of the Department of Forestry & Natural Resources, Punjab Agricultural University, Ludhiana for two years 2019-20 and 2020-21. The growth and yield parameters of cucurbit varieties planted at different times under poplar block plantation were studied. It involved field experiment, including two environments (poplar and open) as main plot, three planting times (Mid-December, Mid-January and Mid-February) as sub-plots and three varieties (PCK-1, PPH-1 and PAU MK-1) as sub-sub plots with three replications in split-split plot design. The soil texture of the experimental area was loamy sand. Available N, P and K and organic carbon content was observed higher under poplar based agroforestry system than open conditions. The tree growth parameters such as diameter at breast height, tree height and crown spread increased with increase in age of trees (5 to 6 years). Maximum leaf shedding under 5 and 6 year plantation was observed from mid-November to end-December and by end-January complete leafless stage was attained. Leaf area index (LAI) of poplar trees started increasing from mid-March and reached maximum from May onwards with the development of full-fledged canopy. The average temperature was recorded relatively higher under open conditions as compared to poplar plantation whereas relative humidity followed opposite trend of temperature. A wide fruit yield variation was observed among the three varieties. PPH-1 was having heavier fruit weight, so it recorded highest fruit yield of 35.52 t/ha and 34.53 t/ha, while lowest fruit yield was recorded in PCK-1(18.57 t/ha and 18.03 t/ha) during first and second year, respectively. However, PCK-1 gave more number of fruits per harvest than the other two varieties. Mid-January (34.98 t/ha and 34.3 t/ha) planted crop gave significantly higher yield than mid-December and mid-February planted crop. The percentage reduction in fruit yield recorded under 5-year-old canopy was 21.97, while under 6-year-old canopy it increased to 24.37. PCK-1 was short duration variety which was harvested in 80.46 days while PAU Magaz kadoo-1 took 93.77 days. The fruit shape index was calculated highest for PAU MK-1 (0.99, 0.94) followed by PPH-1 (0.98, 0.89) and least for PCK-1 (0.85, 0.76) during both the years. Hull-less seeded variety PAU MK-1 recorded highest seed yield (6.17 and 6.07 q/ha) and least percentage reduction in seed yield (21.8 and 23.0) during the two years. Thus, better variety for snacks and oil-seed purpose compared to other varieties. Therefore, based on present study it is concluded that all the three cucurbit varieties should be planted in mid-January under poplar-based agroforestry for vegetable and seeds purposes to enhance productivity and diversification from conventional rice-wheat cropping system.

Keywords: Agroforestry, poplar, cucurbit varieties, planting times, fruit yield, seed yield, fruit shape index

Signature of Major Advisor **Signature of Student**

ਖੋਜ ਗ੍ਰੰਥ ਦਾ ਸਿਰਲੇਖ	:	ਪਾਪਲਰ ਬਲਾਕ ਪਲਾਂਟੇਸ਼ਨ ਹੇਠ ਵੱਖ-ਵੱਖ ਸਮੇਂ ਤੇ ਲਗਾਏ ਗਏ ਕੁਕਰਬੀਟਾ ਸਪੀਸ਼ੀਜ਼ ਦੇ ਵਾਧੇ ਅਤੇ ਝਾੜ ਦੀ ਕਾਰਗੁਜ਼ਾਰੀ ਦਾ ਮੁਲਾਂਕਣ
ਵਿਦਿਆਰਥੀ ਦਾ ਨਾਮ ਅਤੇ ਪ੍ਰਵੇਸ਼ ਨੰ.	:	ਰਜ਼ੀਆ ਬਾਨੋ ਐਲ-2019-ਐਚ-174-ਐਮ
ਪ੍ਰਮੁੱਖ ਵਿਸ਼ਾ	:	ਜੰਗਲਾਤ
ਸਹਿਯੋਗੀ ਵਿਸ਼ਾ	:	ਸਬਜ਼ੀ ਵਿਗਿਆਨ
ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦਾ ਨਾਮ ਅਤੇ ਅਹੁਦਾ	:	ਡਾ ਆਰ ਆਈ ਐਸ ਗਿੱਲ ਪ੍ਰਿੰਸੀਪਲ ਵਿਗਿਆਨੀ (ਵਣ ਖੇਤੀ)
ਡਿਗਰੀ	:	ਐੱਮ.ਐੱਸ.ਸੀ.
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ਸਾਰ ਅੰਸ਼

ਮੌਜੂਦਾ ਅਧਿਐਨ "ਪਾਪਲਰ ਬਲਾਕ ਪਲਾਂਟੇਸ਼ਨ ਹੇਠ ਵੱਖ-ਵੱਖ ਸਮੇਂ ਤੇ ਲਗਾਏ ਗਏ ਕੁਕਰਬੀਟਾ ਸਪੀਸ਼ੀਜ਼ ਦੇ ਵਾਧੇ ਅਤੇ ਝਾੜ ਦੀ ਕਾਰਗੁਜ਼ਾਰੀ ਦਾ ਮੁਲਾਂਕਣ" ਸਿਰਲੇਖ ਅਧੀਨ ਵਣ ਅਤੇ ਕੁਦਰਤੀ ਸੋਮੇ ਵਿਭਾਗ, ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਦੇ ਮੁੱਖ ਖੋਜ ਖੇਤਰ ਵਿੱਚ ਦੋ ਸਾਲਾਂ 2019-20 ਅਤੇ 2020-21 ਦੌਰਾਨ ਕੀਤਾ ਗਿਆ। ਪਾਪਲਰ ਬਲਾਕ ਪਲਾਂਟੇਸ਼ਨ ਦੇ ਤਹਿਤ ਵੱਖ-ਵੱਖ ਸਮੇਂ ਬੀਜੀਆਂ ਗਈਆਂ ਕੁਕਰਬਿਟ ਕਿਸਮਾਂ ਦੇ ਵਾਧੇ ਅਤੇ ਉਪਜ ਦੇ ਮਾਪਦੰਡਾਂ ਦਾ ਅਧਿਐਨ ਕੀਤਾ ਗਿਆ। ਤਜ਼ਰਬੇ ਨੂੰ ਸਪਲਿਟ-ਸਪਲਿਟ ਪਲਾਟ ਡਿਜ਼ਾਈਨ ਵਿਧੀ ਤਹਿਤ ਦੋ ਵਾਤਾਵਰਣ (ਪਾਪਲਰ ਹੇਠ ਅਤੇ ਖੁੱਲ੍ਹੇ ਵਿੱਚ) ਦੇ ਨਾਲ ਮੁੱਖ ਪਲਾਟ ਵਜੋਂ, ਪੌਦੇ ਲਗਾਉਣ ਦੇ ਤਿੰਨ ਸਮੇਂ (ਅੱਧ-ਦਸੰਬਰ, ਅੱਧ-ਜਨਵਰੀ ਅਤੇ ਅੱਧ-ਫਰਵਰੀ) ਦੇ ਰੂਪ ਵਿੱਚ ਸਬ-ਪਲਾਟ ਅਤੇ ਤਿੰਨ ਕਿਸਮਾਂ (ਪੀਸੀਕੇ-1, ਪੀਸੀਐਚ-1, ਪੀਏਯੂਐਮਕੇ) ਸਬ-ਸਬ ਪਲਾਟਾਂ ਵਜੋਂ ਰੱਖਿਆ ਗਿਆ ਸੀ। ਜੈਵਿਕ ਕਾਰਬਨ ਦੀ ਮਾਤਰਾ ਅਤੇ ਉਪਲਬਧ ਨਾਈਟ੍ਰੋਜਨ, ਫ਼ਾਸਫ਼ੋਰਸ ਅਤੇ ਪੋਟਾਸ਼ੀਅਮ ਖੁੱਲ੍ਹੇ ਖੇਤ ਨਾਲੋਂ ਪਾਪਲਰ ਅਧਾਰਤ ਵਣ ਖੇਤੀ ਅਧੀਨ ਵਧੇਰੇ ਵੇਖੇ ਗਏ। ਰੁੱਖਾਂ ਦੇ ਵਾਧੇ ਦੇ ਮਾਪਦੰਡ ਜਿਵੇਂ ਕਿ ਛਾਤੀ ਦੀ ਉਚਾਈ 'ਤੇ ਵਿਆਸ, ਰੁੱਖਾਂ ਦੀ ਉਚਾਈ ਅਤੇ ਛੱਤਰੀ ਰੁੱਖਾਂ ਦੀ ਉਮਰ ਵਿੱਚ ਵਾਧੇ (5 ਤੋਂ 6 ਸਾਲ) ਦੇ ਨਾਲ ਵਧ ਜਾਂਦਾ ਹੈ। ਵੱਧ ਤੋਂ ਵੱਧ ਪੱਤੇ ਅੱਧ ਦਸੰਤਰ ਦੇ ਅਖੀਰ ਤੱਕ ਡਿੱਗਦੇ ਹੋਏ ਵੇਖੇ ਗਏ ਅਤੇ ਜਨਵਰੀ ਦੇ ਅਖੀਰ ਤੱਕ ਪਾਪਲਰ ਦੇ ਰੁੱਖ ਪੂਰੇ ਪੱਤਾ ਰਹਿਤ ਹੋ ਗਏ। ਪਾਪਲਰ ਰੁੱਖਾਂ ਦਾ ਲੀਫ ਏਰੀਆ ਇੰਡੈਕਸ (ਐੱਲ.ਏ.ਆਈ.) ਮਾਰਚ ਦੇ ਅੱਧ ਤੋਂ ਵਧਣਾ ਸ਼ੁਰੂ ਹੋਇਆ ਅਤੇ ਮਈ ਤੋਂ ਬਾਅਦ ਪੂਰੀ ਛੱਤਰੀ ਦੇ ਵਿਕਾਸ ਨਾਲ ਵੱਧ ਗਿਆ। ਔਸਤ ਤਾਪਮਾਨ ਖੁੱਲ੍ਹੇ ਹਾਲਾਤਾਂ ਵਿੱਚ ਪਾਪਲਰ ਪਲਾਂਟੇਸ਼ਨ ਦੇ ਮੁਕਾਬਲੇ 'ਤੇ ਉੱਚਾ ਦਰਜ ਕੀਤਾ ਗਿਆ ਜਦੋਂ ਕਿ ਔਸਤ ਨਮੀ ਤਾਪਮਾਨ ਦੇ ਉਲਟ ਰਿਕਾਰਡ ਕੀਤੀ ਗਈ। ਤਿੰਨੋ ਕਿਸਮਾਂ ਵਿੱਚ ਫ਼ਲਾਂ ਦੇ ਝਾੜ ਵਿੱਚ ਵਿਸ਼ਾਲ ਤਬਦੀਲੀ ਵੇਖੀ ਗਈ। ਪੀਪੀਐਚ-1 ਦੇ ਫਲਾਂ ਦਾ ਭਾਰ ਬਹੁਤ ਜ਼ਿਆਦਾ ਸੀ, ਇਸ ਲਈ ਇਸ ਨੇ ਦੋਵਾਂ ਸਾਲਾਂ ਦੌਰਾਨ ਸਭ ਤੋਂ ਵੱਧ ਟਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ (35.52 ਅਤੇ 34.53) ਝਾੜ ਰਿਕਾਰਡ ਕੀਤਾ, ਜਦੋਂ ਕਿ ਸਭ ਤੋਂ ਘੱਟ ਫਲਾਂ ਦੀ ਪੈਦਾਵਾਰ ਪੀਸੀਕੇ-1 (18.57 ਅਤੇ 18.03 ਟਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ) ਦਰਜ ਕੀਤੀ ਗਈ। ਜਨਵਰੀ ਦੇ ਅੱਧ ਵਿੱਚ ਲਗਾਈ ਗਈ ਫ਼ਸਲ ਦਾ ਝਾੜ (34.98 ਅਤੇ 34.3 ਟਨ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ) ਦਸੰਬਰ ਦੇ ਅੱਧ ਵਿੱਚ ਅਤੇ ਫਰਵਰੀ ਦੇ ਅੱਧ ਵਿੱਚ ਲਗਾਈ ਗਈ ਫ਼ਸਲ ਨਾਲੋਂ ਕਾਫੀ ਜ਼ਿਆਦਾ ਸੀ। 5 ਸਾਲ ਦੀ ਪਲਾਂਟੇਸ਼ਨ ਹੇਠਾਂ ਉਗਾਈ ਗਈ ਫ਼ਸਲ ਦਾ ਝਾੜ 21.97 ਪ੍ਰਤੀਸ਼ਤ ਘੱਟ ਸੀ, ਜਦੋਂ ਕਿ 6 ਸਾਲ ਦੀ ਪਲਾਟੇਸ਼ਨ ਹੇਠਾਂ ਝਾੜ ਹੋਰ ਘੱਟ ਗਿਆ (14.37)। ਪੀਸੀਕੇ-1 ਘੱਟ ਸਮੇਂ ਵਿੱਚ ਤਿਆਰ ਹੋਣ ਵਾਲੀ ਕਿਸਮ ਸੀ ਜਿਸ ਦੀ ਕਟਾਈ 80.46 ਦਿਨਾਂ ਵਿੱਚ ਕੀਤੀ ਗਈ ਹੈ ਜਦੋਂਕਿ ਪੀਏਯੂ ਐਮਕੇ-1 ਨੇ 93.77 ਦਿਨ ਲਏ। ਪੀਏਯੂ ਐਮ ਕੇ-1 ਵਿੱਚ ਦੋ ਸਾਲਾਂ ਦੌਰਾਨ ਸਭ ਤੋਂ ਵੱਧ ਬੀਜ ਦਾ ਝਾੜ (6.17 ਅਤੇ 6.07 ਕਿਲੋ/ਹੈਕਟੇਅਰ) ਦੇਖਿਆ ਗਿਆ ਅਤੇ ਪਾਪਲਰ ਪਲਾਂਟੇਸ਼ਨ ਵਿੱਚ ਖੁੱਲ੍ਹੇ ਖੇਤ ਦੇ ਮੁਕਾਬਲੇ ਬੀਜ ਦੇ ਝਾੜ ਵਿੱਚ ਘੱਟੋ ਘੱਟ ਪ੍ਰਤੀਸ਼ਤ ਕਮੀ (21.8 ਅਤੇ 23.0%) ਦੇਖੀ ਗਈ। ਇਸ ਲਈ, ਮੌਜੂਦਾ ਅਧਿਐਨ ਦੇ ਅਧਾਰ ਤੇ ਇਹ ਸਿੱਟਾ ਕੱਢਿਆ ਗਿਆ ਹੈ ਕਿ ਰਵਾਇਤੀ ਝੋਨਾ-ਕਣਕ ਫ਼ਸਲ ਪ੍ਰਣਾਲੀ ਤੋਂ ਵਿਭਿੰਨਤਾ ਲਈ ਤਿੰਨੋਂ ਕੁਕੂਰਬਿਟ ਕਿਸਮਾਂ ਨੂੰ ਪਾਪਲਰ ਅਧਾਰਤ ਵਣ ਖੇਤੀ ਅਧੀਨ ਸਬਜ਼ੀਆਂ ਅਤੇ ਬੀਜਾਂ ਦੀ ਪੈਦਾਵਾਰ ਲਈ ਅੱਧ ਜਨਵਰੀ ਵਿੱਚ ਲਗਾਇਆ ਜਾ ਸਕਦਾ ਹੈ।

ਮੁੱਖਸ਼ਬਦ: ਵਣ ਖੇਤੀ, ਪਾਪਲਰ, ਕੁਕੂਰਬਿਟ ਕਿਸਮਾਂ, ਲਗਾਉਣ ਦਾ ਸਮਾਂ

ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

%	:	Percent
/	:	Per
×	:	Multiply
C.D.	:	Critical Difference
cm	:	Centimeters
DBH	:	Diameter at Breast Height
e.g.	:	For example
et al	:	others
etc.	:	Etcetera (and so on)
Fig.	:	Figure
FSI	:	Fruit Shape Index
FYM	:	Farm Yard Manure
g	:	Gram
i.e.	:	That is
kg	:	kilogram
m	:	Meter
PCK-1	:	Punjab Chappan Kadoo-1
PMK-1	:	PAU-Magaz kadoo-1
q/ha	:	Quintal Per Hectare
t/ha	:	Tonne Per Hectare
viz.	:	Videlicet (Namely)
w.r.t	:	with respect to
yr	:	Year

CHAPTER I

INTRODUCTION

Punjab with 1.53 percent of the total geographical area of the country, has contributed 20.9 percent of rice and 32.6 percent of wheat to central pool during 2019-20 (Anonymous 2020b). But the emerging scene of Punjab agriculture has some serious concerns. The dominated rice-wheat cropping system in the state is causing a serious damage to its natural resource base. Crop diversification from paddy based cropping system could be an effective strategy to produce more from depleting and shrinking resources (Singh *et al* 2016). The recorded forest and tree cover of the state is 1848 and 1592 square km, respectively which is 3.67 and 3.16 percent of its geographical area (Anonymous 2019). Agroforestry is one of the contrivances to fulfill both, that is, increasing the forest or tree cover (as visualized in the National Forest Policy, 1988) and sustainable use of natural resources. It can fulfill the requirement of both industry and fuel wood. Merging trees and crops under agroforestry give supplementary revenues from fruits, fuel wood and timber along with crop income. A study done by Singh and Pandey (2011) addressed low adoption of agroforestry as a challenging aspect in India. It was stated that more time and expenses need to be invested for developing a sustainable tree mixture for agroforestry systems. In addition to this, management practices like pruning do play a key role to get optimum production under an agroforestry system. Different agroforestry systems are predominant in different agro-climatic regions of India and occupy certain area. Poplar based agroforestry systems are very predominant in Indo-Gangetic Plains of northern India (Rizvi *et al* 2020). It has shown huge potential as an exotic industrial timber since many years in this region (Kaur *et al* 2010). Lack of market, small land holding, lack of awareness, late returns and restrictions on felling and transport of trees are some of the reasons behind limited adoption of agroforestry (Pandey *et al* 2020).

The term agroforestry, coined in late 1970s, is defined as a sustainable natural resource management system that by the addition of trees on agricultural landscape provides a wide range of environmental, economic and sociocultural benefits. Agroforestry, though an old practice was regulated for the first time when International Council for Research in Agroforestry (ICRAF) came into existence in 1977. Agroforestry practices are increasingly recognized as a beneficial land use practices and are thus becoming more widespread both in developed and developing countries. In India, it can be seen by the launching of National Agroforestry Policy by the government in 2014. It shows their commitment to support this land use practice. To expand tree plantation along with crops and/or livestock, to enhance overall productivity, decreasing unemployment, generating additional source of income and livelihood support to small landholders are the objectives under this policy. There is vast diversity in agroforestry systems within the country. The systems vary extremely in their species diversity, structural complexity, productive and protective attributes and also in socioeconomic dimensions. The association between trees and crops or pastures can be sequential (temporal interaction) or simultaneous (spatial interaction) (Somarriba 1992, Torquebiau 2000). Some of the basic objectives under agroforestry policy are strengthening research in agroforestry, improving the productivity, employment and livelihood opportunities of rural families. Agroforestry has been recognized as a component of climate-smart agriculture (Newaj *et al* 2015 a, b). It is a constructive approach for soil carbon sequestration to mitigate the impact of climate change under Clean Development Mechanism of the Kyoto Protocol (Nair 2007). Agroforestry, along with reforestation and afforestation projects form part of numerous mandatory and voluntary carbon-offset trading schemes globally (Diaz *et al* 2011, Olhoff *et al* 2015).

Agroforestry is one of the best options for meeting day-to-day needs of the people and restoration of the degraded environment, besides providing a great opportunity for the rural development and mitigating the climate change effects (Arunachalam *et al* 2020). It can perform a chief role in getting the desired level of diversification along with sustainability. It aids vulnerable populations adapt to the negative consequences of climate change. The competitive position of the agricultural sector can be improved by agroforestry (Kumar *et al* 2020a). Suitably designed agroforestry systems protect forage and crops, increase their production, soil and water reservoir protection, conserve energy, enhance systems richness, create supplementary wildlife habitat and landscape diversity increases. The control of weeds, wind breaker, control of soil erosion, maintenance and improvement of soil fertility, fencing and carbon sequestration in soil are the service function of agroforestry (Gupta *et al* 2009, Nair *et al* 2009). It is also seen as an important tool in the ecosystem approach for agrobiodiversity conservation which is promoted by the Convention on Biological Diversity (CBD). Although crops yield declines in intercropping under agroforestry systems, the judicious and careful selection of varieties may lessen the overall economic losses. Agroforestry systems can lessen nitrate leaching, increase carbon sequestration, and increase pollination services (Kay *et al* 2018). Agroforestry has ability to decrease recalcitrant pollutants, such as nitrogen and trichloroethylene (TCE), from groundwater plumes much more economically compared to costly alternatives (such as ion exchange, reverse osmosis or chemical and biological treatment methods). Natural bacterial endophytes found in poplar trees rapidly metabolize TCE, changing it into chloride ions (Doty *et al* 2017). Due to large-scale demand from the pulp and paper industries, commercial agroforestry is also gaining importance in India (Chavan *et al* 2015). Agroforestry contract farming comprising industry, farmers, research and financial institutions is increasing in some states. In some rainfed regions of India, agroforestry reduce community dependence on forests. Fast growing trees under agroforestry are an attractive alternative to meet the demand of biomass for renewable energy as they reduce land competition for food production and biomass in combination with forest benefits (Pretzsch *et al* 2017).

Populus deltoides, commonly known as cottonwood poplar is native to North America. This deciduous tree belongs to the family Salicaceae. Globally poplar plantations cover 9.4 million ha which is more than double the land used about 15 years ago (Monson *et al* 2020). This is the most widely planted species of poplar in India and was introduced in the late 1950s. It is planted in plains of North-West India, *i.e* Punjab, Haryana, Western Uttar Pradesh and to some extent in Uttarakhand and Himachal Pradesh. It is the keystone of agroforestry in irrigated plains of Northern India. Poplar as an agroforestry component aids in maintaining soil health by adding organic matter in the form of leaf litter and also helps in regulating the nutrient cycle. Poplars have proved to be very valuable in satiating the demand for timber in areas lacking natural forests, particularly in the northern hemisphere. Poplar as a source of bioenergy, is a renewable substitute to fossil fuels. The farmers of Punjab, Haryana, and Uttarakhand grow intercrops with poplar based agroforestry in block plantation (Dhiman 2012a). Due to sensitivity of poplar to waterlogged conditions, it can check the vicious cycle of wheat-paddy rotation, which lowers the water table and becoming unsustainable for crop production in this region (Chauhan *et al* 2012b).The major intercrop in poplar is wheat followed by sugarcane, turmeric, sorghum, berseem fodder and maize. Poplar based agroforestry system is more beneficial and helpful in doubling farmers' income over conventional agriculture in northwestern India (Chavan and Dhillon 2019).

In temperate agroforestry systems, the poplar rows increases the abundance of many soil fungal and bacterial groups than the crop rows under agroforestry and monoculture croplands (Beule *et al* 2020).. Poplar is now a raw material for around three dozen products (Dhiman 2012b). Poplar based agroforestry systems play a major role in fulfilling the requirement of wood based industries and we have to aware people for promoting this species. The farmers prefer poplar in an agroforestry system because of its short rotation period, winter deciduous, easy availability of quality planting material, soil enriching, good economic return with easy marketing and its compatible nature with different agricultural crops (Sharma and Sah 2020). An average farmer earns 46 % higher income from poplar-based agroforestry system compared to rice-wheat monocropping arrangement (Deswal *et al* 2014). Growing fast growing trees (like poplar) along with arable crops will not only improve the sustainability of farming systems, but also diversify farmer's income, provide new products to the wood based industry, meet increasing energy requirements, generate employment and create different landscapes of high value for the generations to come. The trees on the farm also sequester carbon in different tree components and in the soil underneath. Its introduction in agricultural landscape may be a beneficial tool to lockup the carbon and increase soil carbon (Chauhan *et al* 2012c).

Cucurbitaceae is a large plant family consisting of 825 species within 118 genera. Members of this family are referred to as cucurbits. Pumpkin and squashes are major vegetable crops of this family. These cucurbits are of American origin and were grown in Peru as early as 2000 B.C.E (Nesom 2011). It is widely cultivated in Africa, Latin America, Southern Asia, United States and India. Pumpkins are categorized by monoecious plants with sprawling vines. These are commonly referred to cultivars having round fruits and used upon maturity for baking or feeding. On the other hand, squashes are those cultivars having edible immature fruits with a soft skin. It is grown from warm tropical to cool temperate regions. They have longer shelf life as compared to most of the vegetables. These are warm-season crop and require dry weather with abundant sunshine. The soil should be loamy, well drained and rich in organic matter to acquire good yield (Anonymous 2020a). In India, summer squash is cultivated on a limited scale in Punjab, Uttar Pradesh, Delhi, Himachal Pradesh and hills of Uttarakhand. Attributes like ease in cultivation, rapid growth, high yield and off-season nature of crop lead to higher return per unit area under small and scattered land holding, hence attracting small and marginal vegetable growers toward its cultivation (Bhatt *et al* 2011). Summer squash ranks high in economic importance among vegetable crops worldwide.

With proper management practices (like tillage) and a good cover crop, pumpkin and squashes shows good yield attributes in seed quantity, fruit etc. These are cultivated for fruits (immature and mature) and seeds for oil and snacks. Pumpkin has accumulated considerable diversity in vegetative, reproductive and physiological characters over the years. Cultivation of pumpkins are considered easy, even without incentive treatment it can have good growth and production. Various nutrition in pumpkin make it favorable food source. It helps to improve the nutritional status of people, mainly the vulnerable groups with respect to vitamin-A requirement. To address the issues like food security and sustainability, this multipurpose crop could be cultivated under poplar-based agroforestry system as there is more productivity and reliability in production in intercropping system. The risk of crop failure has been shown to reduce by intercropping, by increasing the crop yield stability over time. Biodiversity is created in the cropping systems through intercropping and is considered to make the systems more resistant against environmental perturbations, thus enhancing food security. Greater stability of yield in intercropping over monoculture has been observed in many studies (Willey and Reddy, 1981).

Keeping the above facts in mind, the present study was planned to assess the performance of high value crops such as pumpkin and summer squash varieties under the block plantation of poplar with objectives:

a. To assess the growth and yield parameters of pumpkin (*Cucurbita moschata*) and summer squash (*Cucurbita pepo*) varieties under block plantation of poplar

b. To evaluate optimum time for transplanting pumpkin and summer squash under poplar

CHAPTER II

REVIEW OF LITERATURE

The soil health has considerably degraded over the years in Punjab by the traditional rice-wheat cropping pattern. This is due to indiscriminate use of pesticides, fungicides, fertilizers and other chemicals inputs. The pressure on land resources has increased many times in recent years due to population explosion and related demands. There is a requirement of diversification of farm activity and better use of environmental resources. Agroforestry can be one of the most sustainable options for this purpose. Simply, agroforestry is defined as the deliberate growing of woody perennials on the same area and at the same time as agricultural crops and/or fodder plants. Agroforestry is neither new nor unique for Indian farmers as it is being adopted since long primarily for the need of fodder, fuel, fruits while saving the environment in complementary ways (Bijalwan 2013). Trees on farmland ameliorate the ecosystem by regulating microclimate of site and changing physical structure, infiltration capacity, moisture regime and other chemical properties of soils. Furthermore, litter fall, root extension, and crown expansion aid nutrient cycling and organic matter accumulation in the topsoil (0-15 cm), resulting in improved root zone soil characteristics (Mukhopadhyay *et al* 2016). Now agroforestry has been recognized globally as having the potential to achieve ecosystem sustainability while improving agricultural productivity, profitability, and variety, as well as minimising the effects of climate change. The global diversity of tree species cultivated with agricultural crops is enormous. The structural complexity, species diversity, productive and protective attributes of agroforestry systems vary greatly. International policy gatherings such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity have recognised the potential of agroforestry to contribute to sustainable development (CBD). Among various commercial tree species under agroforestry systems, poplar is widely accepted for its lucrative returns, compatibility with agricultural crops and resource conservation (Chaturvedi and Panday 2001). Poplar constitutes the backbone of agroforestry in the Indogangetic plain. Except for paddy, most *rabi* and *kharif* crops can be successfully produced in poplar block plantations during the early years. With appropriate management of poplar based agroforestry system, farmers are producing an average of 100 q of wood/acre/year and yielding an income ranging from Rs 70,000 – Rs 80,000/acre/year (Gill *et al* 2015).

In this chapter an attempt have been made to review the literature on various aspects of the study. The main emphasis has been given on the “Evaluation of growth and yield performance of *Cucurbita* spp. planted at different times under poplar block plantation". The literature is reviewed under different sub categories:-

2.1 Agroforestry - a climate smart agriculture for carbon sequestration

2.2 Performance of different crops under farm grown trees

2.3 Soil properties and nutrient status under poplar-based agroforestry system

2.4 Effect of planting time on crops under poplar-based agroforestry systems

2.5 Pumpkin and summer squash - important crops among cucurbits

2.1 Agroforestry- a climate smart agriculture for carbon sequestration

Under National Initiative on Climate Resilient Agriculture (NICRA), ICAR project the carbon sequestration potential of agroforestry system existing on farmer's field was studied in various district of Indo-Gangetic Plains (Chavan *et al* 2015). A field survey was conducted through transect walk in the districts. The various data including total net sown area, total areas of districts, climatic parameters were collected from Agriculture Department at each district. The carbon sequestration potentials of AFS under IGP with 10 trees/ha was estimated as 0.17 Mg C/ha/yr. The average SOC was 11.0 t C/ha in baseline (2013) and it would be 13.0 t C/ha after simulation period of 30-years. Distribution of a large extent of agroforestry on farmers' field was seen which contributes to mitigation and adaptation to climate change.

Rizvi *et al* (2020) estimated area under poplar plantations and assessed biomass production and carbon stock for some districts of Punjab and Haryana. Study concluded that poplar based agroforestry systems occupy sizeable area in Punjab and Haryana states of Indo-Gangetic Plains in India. Poplar-based agroforestry systems have significant contribution towards increasing green tree cover as well as reduction in atmospheric carbon di oxide through carbon sequestration in these states.

The analysis by Nath *et al* (2021) gave insights in to the variation in carbon sequestration in agroforestry with climatic and altitudinal zones in India. With an increase in 5% of current area under agroforestry at 5-years intervals, the total CO_2 eq sequestered under agroforestry is in excess of India's projected total emissions by 2030 and 2050. In addition to providing potential non-climate benefits, agroforestry practices also offer opportunities for creating synergies between both adaptation and mitigation actions. Thus, recommended the inclusion of agroforestry in India's National Determined Contribution to the UNFCCC.

Mishra *et al* (2019) examined the potential of *Populus deltoides* based agroforestry system in terms of sequestering carbon and other multiple benefits in Northern India. It showed that carbon sequestration in agroforestry increased with age of agroforestry. It mentioned agroforestry systems as a proven low cost technology to reduce greenhouse gas emissions for mitigating the impact of climate change. By improving biological and soil productivity, *Populus deltoides* agroforestry systems help in sequestration of carbon.

The carbon sequestration potential, carbon emission, and cost benefit ratio of wheat varieties was compared under open farming and poplar based agroforestry system (Kumar *et al* 2020a). Field experiment was carried out at Pantnagar, India. The experimental plots were laid out in open farming and poplar based agroforestry system, and four varieties of wheat, PBW-373, PBW343, UP-262 and VL-907, with three replications. Higher biomass production was recorded in poplar based agroforestry system, resulting in higher carbon stock, carbon sequestration and certified emission reduction and subsequently lower net emission than open farming. Soil organic carbon was also increased in wheat under agroforestry systems due to litter fall and gave higher monetary returns in terms of net return, B:C ratio and carbon price ($ 876.29/ha, 1.83 and $ 744.27/ha) than under open farming. Among wheat varieties VL-907 recorded maximum net return and B: C ratio ($ 914.52/ha and 2.12) followed by PBW-343. Thus, it can be concluded that the impacts of greenhouse gases, global warming and climate change as a whole can be reduced or improved through agroforestry, making agricultural production systems more profitable as well.

Farmer livelihood strategies and attitudes in response to climate change in agroforestry systems in Kedougou, Senegal were analysed (Papa *et al* 2020). Results showed that farmers readily observe changes in climate (actual or not) and incorporate this knowledge into the long-term management of agricultural systems. Farmers also have a strong knowledge of ecological principles directly related to the management of soil, food production, and management of forests and forestry products. The farmers use trees to adapt and cope by reducing vulnerability to variations in climate.

2.2 Performance of different crops under farm grown trees

In southern Xinjiang Province, China, Qiao *et al* (2020) looked into the effects of jujube and walnut trees' shading on wheat quality and productivity in agroforestry systems. Shading by walnut trees reduced grain output while increasing N and P concentrations, as well as protein and wet gluten content. Although the understory of the jujube-based agroforestry system reduced mean daily PAR by 23.2- 25.5 percent, there was no effect on grain yield, its components, florets, spikelets, N and P concentrations, protein and wet gluten contents. Jujube-based intercropping systems are thus sustainable in Xinjiang, as jujube trees do not reduce the yield or quality of intercropped wheat output. Selective felling and pruning, as well as increased tree spacing, can help to minimise competition for light between walnut and wheat trees in new walnut-based agroforestry systems.

Schwerz *et al* (2020) assessed growth, yield and climate traits in agroforestry systems in Southern Brazil. It revealed that crops and trees interact dynamically as a result of variations in the interception of solar radiation by trees in time due to the effect of tree age and its arrangement. Using canonical correlation analysis, the groups of climatic variables and tree growth variables are not interdependent, as the incident solar radiation and minimum air temperature were the key climatic variables that affected tree growth. Tung trees were affected by frost occurrence during the winter season. These facts are significant for establishing agroforestry systems and particularly through the selection of suitable species combinations.

Kumar *et al* (2020c) studied the impact of silver oak (*Grevillea robusta*) and poplar (*Populus deltoides*) based agroforestry systems on the growth and yield characteristics of several wheat (*Triticum aestivum*) varieties in the Dehradun region. The results indicated that although agroforestry systems may reduce grain yield, the careful and judicious selection of varieties may lessen total financial losses. The grain production from VL Gehun 829 variety under Poplar and Oak based agroforestry systems was 36.88 q/ha and 36.71 q/ha respectively, which revealed increase in grain yield under agroforestry systems in comparison to the open condition.

Sharma and Sah (2020) studied the comparative performance of wheat varieties (UP-2526, UP2565, UP-2628, and DPW-621-50) under poplar and eucalyptus-based agroforestry system. The field experiment included three main plots (open farming, poplar and Eucalyptus agroforestry system) and four sub plots (different wheat varieties) in split plot design. The growth and yield parameters of wheat crop were recorded during *rabi* season. The higher wheat yield was under poplar compared to eucalyptus-based agroforestry system. It may be due to their leaf shedding habit.

The performance of six wheat varieties was studied under poplar based agroforestry systems and open condition in Uttarakhand (Kumar *et al* 2019). Growth attributes and yield of wheat, above-ground, below-ground and total biomass production as well as carbon sequestration and available N, P and K were higher in agroforestry system than open farms. Among wheat varieties, VL-907 recorded higher yield attributes as well as grain, straw and biological yield. Likewise, six wheat varieties viz. HD 3086, PBW 677, PBW 725 as new and PBW 658, WH 1105, HD 2967 as prevalent were evaluated under three spacing of 4-year-old poplars as well as in open conditions (Virk *et al* 2017). On an average, there was 28 percent reduction in wheat grain yield under poplar plantation as compared to that in open. The presence of lower PAR under poplar is the major limiting factor affecting the grain yield. Wheat variety PBW 725 recorded highest grain yield of 39.3 q/ha followed by HD 3086 (37.4 q/ha) which was statistically at par with PBW 677 (36.4 q/ha). The uptake of N, P and K by wheat grain and straw was higher in open conditions than under the trees. N uptake was higher in grain while P and K uptake were higher in straw. In grain, N uptake was maximum in PBW 725 while that of P and K uptake was maximum in HD 3086. However in straw , maximum uptake of N and K was recorded in PBW 677 and P by WH 1105. But the total uptake of N, P and K was maximum in wheat variety PBW 725, WH 1105 and PBW 677, respectively.

Singh *et al* (2019b) studied the performance of different potato cultivars [Kufri (K.) Pukhraj, K. Badshah, K. Jyoti, K. Pushkar, K. Chipsona-1 and K. Chipsona-3] under 5 and 6 years old poplar block cultivation. The different growth and yield attributes were studied under two growing environments (open field vs. intercrop in poplar plantation). Under the agroforestry system, there is a change in the micro-climatic conditions which influenced the life cycle of the intercrop grown under it. Appropriate time of planting and shade tolerant cultivars boost the vegetative growth and improve the yield of crop. The maximum yield was recorded in potato cultivar K. Pukhraj when planted in second week of November.

Singh *et al* (2019c) examined the effects of leaf litter decomposition and its impact on baby corn intercrop under poplar based agroforestry system. The straw yield, cob yield, and weight of leaf litter were recorded. These values were recorded more under poplar as compared to control.

An experiment was conducted at the Char Kalibari during the period from November 2012 to March 2013, under the Department of Agroforestry, Bangladesh Agricultural University, Mymensingh (Hossain *et al* 2014). Different tree species planted during the year 2011 were eucalyptus, lombu, mahogany, karanja, guava, mango and lemon. . Yield production of bitter gourd in association of these trees was ranked as Karanja > Mango > Mahogony > Guava > Lombu > Eucalyptus > Lemon.

Crop composition, yield, biomass, net primary productivity (NPP), carbon stock and carbon sequestration in agri-silviculture (AS) and agri-horticulture (AH) agroforestry systems of Central Himalaya was assessed (Adhikari *et al* 2020). It involved field survey for the selection of AS (poplar + wheat) and AH (mango + wheat) systems practiced by the farmers in the region. In each agroforestry system, the wheat and tree species were evaluated. The yield, net primary productivity, carbon sequestration and soil nutrients had shown that the AS (poplar + wheat) system is better than AH (mango + wheat) system. The yield of wheat was higher in AS than in AH agroforestry system, however yield of wheat in both AS and AH systems was lower than sole system. Thus, on the basis of their study, it was recommended to adopt the AS system as it has provided better outputs from the productivity, carbon sequestration and sustainability.

A study was done to assess crop management under trees for improved production and income for farmers (Osman *et al* 2011). Pearl millet (*Pennisetum glaucum*) and cowpea (*Vigna unguiculata*) crops were sown under and outside the shade of six randomly selected *Parkia biglobosa* trees during one season in south-central Burkina Faso. Control plots were established outside the tree canopy. The crops were intercropped in two different patterns using the replacement method and compared to sole crops. Days to flowering were recorded and yields were measured, and Land Equivalent Ratio (LER) and Monetary Advantage Index (MAI) was calculated. Intercropping with two rows of cowpea and one row of millet gave considerably higher economic benefit than mixture with one row of each of the crops. The results indicated that intercropping could improve the system's productivity, increase the income for farmers, and compensate losses in pearl millet under the canopy.

Do *et al* (2020) evaluated alternative agroforestry systems for sustainable land management and livelihood improvement in northwest Vietnam. The performance of fruit tree-based agroforestry and sole cropping were compared. Report showed agroforestry improved ecosystem services by controlling surface runoff and erosion, increasing soil fertility and improving resilience to extreme weather. Within a few years, agroforestry practices with fruit trees can be more profitable than sole-crop cultivation. To expand agroforestry in northwest Vietnam, financial supports to meet the higher investment costs for agroforestry and for better value chains with market stability are preconditions for farmers.

Niether *et al* (2020) gave a meta-analysis of 52 articles that directly compared cocoa agroforestry systems and monocultures. By inductive, multi-dimensional approach, they analyzed the differences in cocoa and total system yield, economic performance, soil chemical and physical properties, incidence of pests and diseases, potential for climate change mitigation and adaptation, and biodiversity conservation. Cocoa agroforestry systems recorded good results than monocultures in most indicators. Cocoa yields in agroforestry systems were 25% lower than in monocultures, but total system yields were about ten times higher, contributing to food security and diversification in incomes.

Varah *et al* (2020) evaluated whether agroforestry (AF) can offer increased pollination service compared to monoculture (MC) systems. Six UK sites, each containing an AF and a MC system, were studied over three years. For the magnitude and stability, wild pollinator abundance and diversity respectively, of the pollinating community were used as proxies. Study presented strong practical evidence that UK AF systems can support greater numbers of wild insect pollinators, greater pollination service and greater wild bee species richness. This could benefit both wild plant populations and insect pollinated agricultural crops in areas near AF systems

Details on how temperate agroforestry systems influence insect pollinators and their pollination services with particular focus on the role of trees and shrubs was analysed (Bentrup *et al* 2019). It indicated that agroforestry practices can provide three benefits for pollinators: (1) providing habitat including foraging resources and nesting or egg-laying sites, (2) enhancing site and landscape connectivity, and (3) alleviating pesticide exposure.

Lepcha *et al* (2019) analysed the plant diversity, structure, uses, and importance of homestead garden for biodiversity conservation in Dzongu area, Sikkim, India. It was done by means of multistage random sampling from a total of 100 households using a semi-structured questionnaire. A total of 102 plant species belonging to 54 families and 72 genera was recorded from the study area. The most dominating habit was observed for trees representing 39 % of species followed by 38 % represented herbs, 7 % represented shrubs. Out of the total documented species, the most dominating plant part used by homestead growers was fruits (45 %) followed by leaves (29 %) and wood (13 %). A baseline data was presented about plant diversity in the home gardens, uses of plants and arrangement of the plants in the home garden.

Temgoua *et al* (2020) analysed the contribution of coffee agroforestry systems (CAFS) to conserve tree diversity and carbon stocks in the western region of Cameroon. Enumeration was carried out in 52 plots laid out in CAFS and in adjacent secondary forest. Allometric method was used to estimate above-ground biomass. Wide differences were recorded between coffee agroforestry systems and the forest in terms of diversity, tree density and carbon stock. Although tree density is much higher in the forest, CAFS contributed significantly to the conservation of woody species because they share in common 60 % of the species with the forest. In CAFS, some forest species were being replaced with non-forest species that are useful and can contribute to income generation and farmers' livelihood. Farmers have mainly oriented their coffee farms towards diversification of production. As a result, the associated trees are mainly introduced or conserved for fruit production, palm oil production and the needed shade for coffee trees. Thus growers should be encouraged to plant/conserve more tree species that are useful but also have good carbon sequestration potential.

To assess the planting pattern, demand- supply gap and economic returns of poplar and eucalyptus species, the socio-economic studies was carried out in six districts *viz*. Raebareli, Barabanki, Gorakhpur, Bahraich, Sonbhadra and Prayagraj (Srivastav and Tomar 2020). The planting pattern of trees showed that on an average, 23 % trees were scattered on farms, 36 % were in blocks/orchards, 24 % were on bunds and 17 % were around homesteads etc. A wide demand supply gap persists due to huge demand of these two species in plywood/veneer and other wood based industries. The results showed that in districts, Gorakhpur, Bahraich and Raebareli where plywood/veneer industry exists; highest demand supply gap of 135450, 151410 and 75230 cft/yr respectively for eucalyptus and 55741,111050 and 48100 cft/yr respectively for poplar was recorded. Thus, there is a great possibility of planting of these two species in the commercial manner in the region of Eastern UP as they are fast growing, exempted from felling and transit permit and availability of market.

Economic evaluation of various agroforestry systems was studied for adoptability due to increasing land pressure and for diversification of traditional cropping system (Chavan and Dhillon 2019). It showed poplar based agroforestry system as more profitable and economically viable than many of the traditional crop rotations. It was concluded that poplar based agroforestry system at spacing of 10 x 2 m was superior over other spacing models with regard to tree growth and crop yield. It would help farmers to double their income (BCR of 1:2.22) in the semi-arid environment of North-western India and would guide farmers to adopt this remunerative practice.

2.3 Soil properties and nutrient status under poplar based agroforestry system

Agroforestry systems have a positive impact on soil characteristics and help in land degradation reversal. Through physico-chemical and ecological changes, trees in agroforestry boost soil productivity (Chauhan *et al* 2012a). The importance of agroforestry arises mainly from soil conservation (Nair 1989). Poplar tree leaf fall in agroforestry systems contributes to the addition of organic matter and nutrients to soil.

Changes in total soil organic carbon (SOC), available phosphorus (P) and potassium (K) were studied (Dhillon *et al* 2020). Soil samples were collected from poplar based agroforestry system varying in age from 2-20 years. Soil plough layer (0-15 cm) had relatively higher SOC concentration, compared with 15-30, 30-45 and 45-60 cm soil depths, respectively. Soil organic carbon decreased significantly with increasing soil depth, regardless of the age of poplar plantation period. The concentration of available-P and K was significantly higher in the surface soil, and decreased with increasing soil depth. The findings concluded that long-term adoption of agroforestry system increased SOC, available-P and available-K concentration in the surface soil with increase in age of agroforestry system and decrease with increasing soil depth.

Salve and Bhardwaj (2020) analysed soil carbon stock and nutrient under three different agroforestry systems *viz.*, Agri-horticulture system (AH), Agrisilviculture system (AS) and Agrihortisilviculture system (AHS) of North-Western Himalayas during the year of 2014-15. Soil tested in the laboratory showed that the organic carbon, extractable phosphorus, calcium and magnesium decreased with an increase in soil depth. Bulk density, particle density and total nitrogen percentage and available potassium (K) were higher at dry temperate high hills. Similarly, pore space percent, soil pH, organic carbon percentage (OC) and extractable phosphorus (P) found to be higher at high hills temperate dry and cold. It was concluded that the soils of cold deserts are suitable for various agroforestry systems.

In a chronosequence of a poplar (*Populus deltoides* Bartr.)-based agroforestry systems in India, the dynamics of soil cationic micronutrients were examined (Kaur *et al* 2020). Soil samples were taken from the fields of village Khehra Bet and other nearby villages in the Ludhiana destrict of Punjab, India. The use of a poplar-based agroforestry system resulted in an increase in overall concentrations of micronutrients such as zinc, copper, iron, and manganese, as well as their chemical pools/fractions, in the soil. Micronutrients were increased and redistributed from unavailable chemical pools (carbonate bound and crystalline Fe-oxides bound) to readily available chemical pools in the soil as a result of the chronosequence of poplar-based agroforestry system as compared to fodder-fodder rotation and fallow/undisturbed land

To determine the soil quality in coconut based agroforestry system, a study was caonducted in Odisha during June 2015 – May 2016 in 15 sizes ranging from 0.1 to 1.5 acre of land holdings (Panda *et al* 2020). Three cropping seasons (kharif, rabi, and summer) were used to visit the selected coconut-based agroforestry systems. Floral composition, plant height, tree number, number of livestock animals and birds, number of common plant species, and other seasonal crops were recorded. The soil chemical analysis was carried out to assess the organic carbon, N, P and K content along with the pH range. The coconut based agroforestry system of Puri district of Odisha was observed to be rich in structure, function and soil chemical status up to holding size of 1.2 acre. The treatments up to 1.2 acre size were found to be well composed of different types of plants such as tree species, fruit plants and seasonal crops along with coconut in four different layers. Out of the 15 treatments, the coconut based agroforestry system of size 0.8 acre was found to be best among the holding sizes studied with regard to structure, function and soil chemical status.

Beule *et al* (2020) analysed temperate agroforestry practices to see their effect on soil microbial communities. The agroforestry croplands were poplar-based alley-cropping systems, in which samples were collected in the tree rows as well as within the crop rows at three distances from the tree rows. When compared to crop rows in agroforestry and monoculture croplands, poplar rows in temperate agroforestry systems enhanced the abundance of various soil bacterial and fungal groups. The stimulation of soil microflora under the tree was likely supported by tree litter (roots, twigs, and leaves) and tree roots. The higher number of denitrification genes in poplar trees suggests that poplar trees may help in denitrification and hence minimise nitrate leaching

To analyse the effects of intensive rice-wheat and poplar-based agroforestry systems existing on a large area, a study was conducted on the distribution of micro and macronutrients in surface soils, as well as the profile of the alluvial soils of Punjab for last 25 years (Dhaliwal *et al* 2020). Soil samples were taken from ten randomly diffused locations each from rice-wheat and poplar-based agroforestry systems. Different physico-chemical properties were measured. Significantly higher levels of available N, P and K, pH and EC reported in agroforestry as compared to rice-wheat system. The effect of these two contrast systems was seen by the release and availability of nutrients (macro and micronutrients) in the soil over its initial levels.

Sharma *et al* (2015) evaluated the changes in physico-chemical properties of soil under poplar plantations in alluvial soil of Punjab. There was much improvement in cation exchange capacity and water holding capacity with increase in cutting cycles of poplar plantations. Further, it was concluded that adoption of agroforestry for long term assist in decreasing soil pH which may improve the availability of nutrients. It would also help in limiting the nutrient loss through leaching and preventing the decline in soil physical health.

Singh *et al* (2014) analysed the soil properties and performance of soybean under poplar based agroforestry system in Tarai belt of Uttarakhand. The open farming system recorded higher soil organic carbon, pH, EC, available N, P, and K as compared to open farming. Growth parameters like germination count, number of trifoliate leaves per plant and plant height were found higher under open farming system as compared to poplar based agroforestry system.

Joslin *et al* (2019) collected soil, biomass, and mulch data over the course of one 9-year crop-fallow rotation and the first two years of the second rotation. The effects of P+K fertilisation and the addition of an N-fixing tree species, *Inga edulis*, on crop and tree biomass production were studied using a split-plot design. Results showed that the simultaneous planting of the staple crop manioc with native tree species, in combination with slash-and-mulch site preparation, can yield two crop harvests and a merchantable timber harvest through the course of one crop–fallow rotation with P + K fertilization, while leaving other tree species for harvest in future crop–fallow cycles.

Soil quality indicators were investigated in three poplar based silvo-arable alley cropping systems in Germany (Beuschel *et al* 2019). Soil microbial activity, microbial biomass C and N and their functional diversity in topsoils were examined. It was observed that tree introduction in arable cropping has enhanced soil quality and ecosystem functioning. A shift towards higher fungal abundance in the composition of main microbial groups was observed.

Fortier *et al* (2020) tested the effects of two unrelated hybrid poplar genotypes (*P. deltoides* × *P. nigra*, genotype D × N-3570 and *P. maximowiczii* × *P. balsamifera*, genotype M × B-915311) and two planting stock types (unrooted whips and bare-root stocks) on growth, biomass, soil nutrient availability and soil microclimate in 15 m wide bioenergy buffers located in the cold temperate region of southern Québec, Canada. Outcomes from the 7th and 8th growing seasons showed that genotype selection had an important influence on soil microclimate and nutrient availability, while planting stock type had little effect on those soil properties. Poplar buffer soils were characterized by cooler temperatures and a lower moisture content compared to the adjacent hayfields, suggesting that such buffers could provide climate and hydrological regulation in temperate agroecosystems. As the plant-soil interactions are strongly affected by hybrid poplar genetics, genotype selection is an important consideration in the design of multifunctional agricultural buffers.

2.4 Effect of planting time on crops under poplar based agroforestry systems

Jyoti *et al* (2019) analysed the effect of planting time on growth and yield of onion under poplar block plantation. The performance of four onion varieties were studied under open condition and under 2- and 3-year-old poplar block plantation (8.0 x 2.5m spacing) for two years. There was reduction in average total bulb yield of onion under poplar than open condition but there is more than 20 per cent increase in growth attributes of poplar. It shows that the loss in yield of onion is being compensated by gain in poplar growth. Out of the four onion varieties, variety PWO 35 recorded higher yield under poplar based agroforestry system.

A study was conducted to optimize the time of sowing in relation to newly released wheat varieties under 4–6 year old poplar block plantation (Gill *et al* 2009). Six widely grown wheat varieties (PBW 343, PBW 502, WH 542, PDW 274, PBW 373 and PBW 509) were intercultivated during three consecutive crop growth seasons at three times of sowing (mid-November, late November and mid-December) under block plantation of poplar (*Populus deltoides* Bartr.) clone G-48. The maximum wheat yield was obtained when crop was sown during first fortnight of November in open as well as under the 4-6 year old poplar plantations compared to further delay in sowing. Best wheat variety under this optimum sowing time as well as under late sown conditions was PBW 502.

Bhandari *et al* (2015) studied the effect of varieties and sowing time on potato under poplar based agroforestry systems. Treatments included early, mid and late sown potato varieties viz., Kufri Jyoti, Kufri Badshah, Kufri Pukhraj and five planting times viz., early-November, mid-November, late- November, mid-January, early-February. Their study showed best combination of sowing time was late-November with variety Kufri Badshah under block plantation of poplar. This gave the highest number of tuber plant, maximum yield plant and maximum total tuber yield per hectare. Late November sown crop showed early germination and recorded higher yield as compared to other sowing times.

Bora *et al* (2019) conducted a field study during *rabi* season of 2015-16 at Pantnagar to study the performance of different wheat varieties (UP-2565, UP-2526, DPW-621-50, and UP-2628) under open and poplar based agroforestry system on different date of sowing (4^{th} November, 24^{th} November and 14^{th} December. The result showed that normal date of sowing (24th November) was much suitable for getting higher yield of wheat under open farming as well as under agroforestry systems in the Tarai region of Uttarakhand.

Oz and Kuscu (2018) studied the effects on sesame seed yield of four sesame (*Sesamum indicum* L.) varieties (Boydak, Golmarmara, Sarisu and Tanas) and four sowing times (1 May, 15 May, 1 June and 15 June) in experimental area of the Uludag University, Mustafakemalpaşa in 2015 and 2016. The highest seed yield was obtained as 1887.8 kg/ha from Gölmarmara variety. In terms of sowing times, the highest average seed yield was obtained from sowings of May 15 and May 1 for years of 2015 and 2016, respectively.

Rahman *et al* (2011) examined the effect of variety and sowing date on the morpho-physiological, yield and yield contributing components of wheat. Results showed that occurrence and duration of different phenophases were significantly affected by differences in varieties and planting dates. It indicated that Shatabdi performed better on yield and yield components and 15 November as suitable for better yield. On the other hand, Shatabdi also gave better performance on yield components under late sowing condition.

Bisht *et al* (2018) conducted experiment in Pantnagar, Uttarakhand during the *rabi* season for two years 2014-15 and 2015-16 to study the comparative performance of wheat varieties under poplar based agroforestry system. Five wheat varieties (PBW-343, UP-2565, WH-711, DBW17 and VL-907) were tested under poplar plantation and in open field during both the years. Among the different wheat varieties grown with poplar, VL-907 gave the better performance under agroforestry system as well as open farming system during both the years of experiments.

A study was done to assess the effect of different sowing time on productivity and economics of summer mungbean (*Vigna radiata* L.) production (Brar *et al* 2017). The demonstrations were carried out in 72 different locations at farmers' fields in Tarn Taran district of Punjab. Summer mungbean variety SML 668 was given to all the farmers. The demonstrations were categorized into seven groups based on sowing dates and standard meteorological weeks from March 11 (11th week) to April 28, 2016 (17th week). The outcome of investigation indicated, overall best performance of summer mungbean when sown between 18th to 24th March (12th standard meteorological week) at all the locations of demonstration.

Meena *et al* (2018) studied response of sowing dates and bio regulators on yield of clusterbean under current climate in alley cropping system in eastern U.P., India. The impacts on yields of cluster bean were evaluated for normal (15 July) and late (30 July) sowing environments and foliar spray of thiourea (500, 1000 ppm) and salicylic acid (50, 100 ppm) at 45 and 60 days after sowing (DAS). The results showed that the foliar application of bio regulators at normal sowing date enhances seed yield of clusterbean by improving the physiological processes.

2.5 Pumpkin and summer squash- an important crop among cucurbits

Ahmed and Khan (2019) focused on nutritional, medicinal, minerals, industrial and technological approaches of the pumpkin. It was observed that peeled pumpkin pulp flour has higher crude fiber content than wheat flour. It can also be used in the treatment of cancer. Due to the presence of beta-carotene, it helps in the treatment of depression in Korea. The members of Cucurbitaceae family have multifunctional uses in life of humans and animals. Thus, there should be more production of these plants which will contribute to livelihood sustainability and livelihood security in India and other regions of the world.

Esang *et al* (2019) studied the potential of using pumpkin intercrop as a way for effective weed management in water yam (*Dioscorea alata*) farm in Nigeria. Due to high number of pumpkin leaves and wide coverage of ground, it serves as a life mulch in the yam field. The study suggested that pumpkin intercrop could effectively lessen weed interference in water yam farm and save time and money, particularly during the time of peak labour demand for other crops.

Elias *et al* (2020) investigated growth, yield and phytosterol of squash (*Cucurbita pepo* L.), medical pumpkin (*Cucurbita pepo* subsp.) and their hybrids. It involved crossing among 15 pure lines of squash and medical pumpkin *pepo* var. *styriaca* at University of Baghdad. The results showed significant differences among genotypes in the studied traits. The parents ST, E1, E3, E6, K3 and K7 showed superiority when compared to other parents in vegetative and flowering growth, earliness of maturity, yield and phytosterol.

Thongney *et al* (2020) studied the effect of different level of vermicompost and FYM on growth and yield of cucumber intercropped with citrus based agroforestry at forest nursery and research centre, SHUATS, Prayagraj, India, during June- September 2017. The experiment involved 9 treatments and 3 replications in randomized block design. The overall best treatment was T8 (Vermicompost @ 2t/ha – FYM @ 15t/ha) which gave the maximum optimistic results in all parameters i.e. the growth and development.

Koocheki *et al* (2018) studied the intercropping benefit of saffron-pumpkin and saffron-watermelon intercropping as a strategy to increase the economic land equivalent ratio under limited irrigation in Iran. There was a marked increase in saffron dried stigma yield and flower number in intercropping system as compared to monoculture. It was due to covering of soil surface by watermelon and pumpkin canopy that reduces soil temperature, evaporation and nutrients loss during saffron dormancy period. Overall, intercropping improves farmers' income and increases land use efficiency.

Xiong *et al* (2010) studied the intercropping of pumpkin under young elm (*Ulmus* spp.) trees to effectively use the barren land with both economic development and ecological improvement. The results showed increase in soil moisture level in elm trees belt-pumpkin intercropping as the pumpkin vines covered the gap between pumpkin and elm trees. The nutritive value and biomass of both pumpkin and elm trees increased remarkably under intercropping than under single cropping. Soil erosion was also less due to pumpkin plantation.

Begum and Kader (2018) conducted a field research at a recently developed alluvial soil in Bangladesh during 2015-16 and 2016-17 winter seasons to select suitable leafy vegetables intercropping with pumpkin for higher productivity, better land and time utilization and maximum economic return. Six leafy vegetables *viz.* radish green, mustard green, jute green, coriander green, red amaranth and spinach were intercropped with pumpkin and compared with sole pumpkin. Results indicated that intercropping leafy vegetables with pumpkin did not reduce pumpkin yield but increased system productivity by 39-120 % over sole cropped pumpkin. All the intercropping combinations performed better than sole pumpkin. Though, the highest system yield (72.7 and 75.6 t/ha), land equivalent ratio (1.74 and 1.75), area time equivalent ratio (1.20 and 1.16), net return (8001 and 8350 USD/ha) and benefit cost ratio (10.3 and 10.7) were obtained in 2015-16 and 2016-17, respectively from pumpkin + spinach system.

The financial feasibility of summer squash cultivation in Tarai region of Uttarakhand during winter - spring season of 2013-14 and 2014-15 was studied (Bhatt *et al* 2016). Among three transplanting dates, summer squash transplanted on 15th January was found to be best with respect to plant growth characters, total yield (373.50q/ha), net return (`2,46,542/ha) and benefit – cost ratio (2.72). Out of 12 treatment combinations, summer squash planted on 15th January under black polyethylene mulch is most profitable in terms of getting maximum benefit - cost ratio of 4.41.

A study was done to determine the yield and quality of three different squash varieties under field conditions with three different cultivation type (Yoldas 2014). The results showed that the varieties had statistically significant effects on yield; on the other hand cultivation methods did not affect the yield statistically significant.

Imnatemsu *et al* (2020) studied the effect of organic and inorganic fertilizers on growth and yield of bottle gourd (*Lagenaria siceraria*) under teak based agroforestry system. The results showed that the application of the combination (50 % NPK + 50 % cow dung manure) to bottle gourd had increased the growth and yield under teak based agroforestry system.

Adam *et al* (2020) evaluated the performance of watermelon in maize/watermelon intercrop under varied row arrangements and cow dung rates in a Sudan Savanna area. It was concluded that row arrangements of 1:2 (i.e. 1 row of maize to 2 rows of watermelon) with application of 15 t cow dung per ha is most suitable for production of watermelon in maize/watermelon intercrop in the Sudan Savana agroecology.

Hadidi *et al* (2011) determined the potential of some summer vegetable crops to intercropping system and to define the best combinations which yield highest production. Four vegetable crops namely bush bean, okra, lettuce and squash were planted in six combinations. Each combination was planted under four different row arrangements (1:1, 1:2, 2:1, 2:2) in the open field. For squash, significantly highest yields were obtained when it was intercropped with bean under 2: 1 and 2: 2 row arrangements as compared with squash yield sole crop.

CHAPTER III

MATERIALS AND METHODS

The present investigation entitled, "Evaluation of growth and yield performance of *Cucurbita* spp. planted at different times under poplar block plantation" was carried out at the research area of the Department of Forestry and Natural Resources, College of Horticulture and Forestry, Punjab Agricultural University, Ludhiana during the year 2019-20 and 2020-21. The details related to experimental site, material used, methodology adopted and observations recorded during the period of investigations are described in this chapter.

3.1 Experimental site

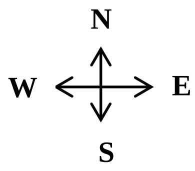
The experimental site was located in the main Research Area of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana. It is located at an elevation of 247 m above the mean sea level and lies at 30°54' latitude and 75°40' longitude. Experiment was conducted there for two consecutive years of 2019-20 and 2020-21 during the *rabi* season.

3.2 Climate

Among six agroclimatic zones of Punjab, Ludhiana region falls under the central agro climatic zone. The region's climate is subtropical, with a long dry season from late September to early June and a rainy season from July to early September, with intense desiccating winds in the summer (May-June) and severe cold in the winter with occasional ground frost (December-January). May and June are the hottest month with extensive evapo-transpiration losses whereas December and January are the coldest months. Usually from October to July, dry conditions prevail in the region of experimental site, except for few light showers received from north- western depressions during the winters.

3.3 Details of agroforestry experiment:

A. Tree species: Poplar (*Populus deltoides*)
   Poplar clone: L-47/88
   Age: 5 and 6 years,
   Spacing: 8 × 2.5 m (N-S direction row spacing)
B. Crop: Cucurbits (*Cucurbita* spp.)
   Plot size: 5 × 1.5 m
   Spacing: 0.45 × 1.5 m
C. Design: Split-split plot design
   No. of replications: 3
   Treatments: 24 (2 environments × 4 planting times × 3 varieties)
   Total no. of plots: 72 (24 treatments × 3 replications)
   Season: *Rabi* 2019-20 and *Rabi* 2020-21



CONTROL								
	NE	**NE**	**NE**		**NE**	**NE**	**NE**	
	S1R1V1	**S1R1V2**	**S1R1V3**		**S3R1V1**	**S3R1V2**	**S3R1V3**	
	S1R2V2	**S1R2V3**	**S1R2V1**		**S3R2V2**	**S3R2V3**	**S3R2V1**	
	S1R3V3	**S1R3V1**	**S1R3V2**		**S3R3V3**	**S3R3V1**	**S3R3V2**	
	S2R1V1	**S2R1V2**	**S2R1V3**		**S4R1V1**	**S4R1V2**	**S4R1V3**	
	S2R2V2	**S2R2V3**	**S2R2V1**		**S4R2V2**	**S4R2V3**	**S4R2V1**	
	S2R3V3	**S2R3V1**	**S2R3V2**		**S4R3V3**	**S4R3V1**	**S4R3V2**	
	NE	**NE**	**NE**		**NE**	**NE**	**NE**	
PATHWAY								

Layout of experimental area

S – Sowing time

R – Replication

V – Variety

Plate 1: Seed sowing in plug trays

Area before land preparation

Preparation of Beds under Poplar

Transplanted seedlings under poplar

Plate 2: Experimental Site

Treatment details:

Main: Environment

Poplar

Open (mono crop)

Sub: Planting time

Mid-December

Mid-January

Mid-February

Mid-March

Sub-sub: three varieties

Punjab Chappan Kadoo-1 (*Cucurbita pepo*) [PCK-1]

Pumpkin hybrid (*Cucurbita moschata)* [PPH-1]

PAU Magaz Kadoo-1 (*Cucurbita moschata)* [PAU MK-1]

3.4 Layout of experiment

In between the tree rows separated at 8 × 2.5 m, plots of 5 × 1.5 m size were prepared. Twenty plants of each variety per replication, spaced 0.45 m apart on both sides of 1.5 m wide beds. To minimise the shade effect on agricultural crops, the tree lines were oriented in north to south direction. Each poplar line contains 18 trees of 5-6 years.

3.4 Cultural practices

a. Nursery raising

For cucurbit varieties, nurseries were raised one month before the transplanting times. The seedlings were transplanted when it reached at two leaf stage.

b. Land preparation

The experimental field was ploughed, harrowed to bring it into fine tilth. Recommended quantity of Farm Yard Manure was applied to the experimental site at the rate of 15 tonnes per acre and thoroughly mixed with soil. Then the area was laid out into subplots of size 5 × 1.5 m with total of 36 plots each under poplar and control, respectively. Sufficient provisions for proper drainage were considered.

c. Manures and fertilizer application

PAU package and practices (Anonymous 2020a) was followed for NPK application in desired doses. Recommended dose of nitrogen (40 kg/acre), P_2O_5 (20 kg/acre**)** and K_2O (15 kg/acre). Half dose of nitrogen and full dose of phosphorus and potassium was applied as basal dose at the time of transplanting and remaining 50 percent of nitrogen was applied as top dressing after 30 days of transplanting.

d. Transplanting

The seedlings of all the three cucurbit varieties were transplanted in four times at an interval of thirty days. For the present study, first transplanting was done in mid-December, second in mid-January, third in mid-February and fourth in mid-March.

e. Irrigation

First irrigation was done after transplanting, for proper establishment of seedlings. For the initial 40 days, seedlings were irrigated at an interval of 15 days, afterwards irrigation was applied at an interval of 7 days. Irrigation requirement at initial period of growth is comparatively less as compared to later period. Method of irrigation used was flooding.

f. Weeding

Weeds obstruct the growth of cucurbits by competing for various growth factors. The critical period for weed competition in cucurbits is up to 30 days after transplanting. The experimental area was kept free from weeds by manual weeding once in 15 days interval during cropping period.

g. Crop protection measures

The experimental area was inhabited by large number of bird species. These biotic factors were one of the reasons for mortality rate. Reflective ribbons were used to protect the crop from birds. The colourful flowers of cucurbits also attract many insects. During adverse weather conditions, cucurbits being frost sensitive, was protected by low plastic tunnels using polyethylene sheets and poplar twigs. It also protected the crop from birds and other biotic factors and helped in checking weed growth. Black and transparent plastic tunnels were used during first and second year, respectively. Plants were also protected from insects like red pumpkin beetle, caterpillar and fruit flies by spraying broad spectrum insecticide like coragen at the rate of 0.4 ml in 1 litre of water.

h. Harvesting

Based on the varied objectives of fruit as vegetable and snack seed purpose, the cucurbit varieties, PCK-1 and PPH-1 were harvested at immature stage for vegetable purpose and hulless variety, PAU-Magaz kadoo-1 at mature stage for seed purpose. Based on the customer preference for small to medium sized fruits, PCK-1 was harvested when it attained a uniform green, disc shaped fruit. PPH-1 hybrid was harvested when it attained a mottled green skin with nearly round fruit. PAU-Magaz kadoo-1 was harvested at maturity stage for seed purpose when fruit gave a stripped orange to golden skin pattern with round shape. PCK-1 is an early maturing variety, was harvested earlier and frequently at two-three days interval than the remaining varieties. Few fruits of PCK-1 and PPH-1 were kept to reach maturity to

Under poplar **Under open**

Plate 3: Manual weeding

Plate 4: Cucurbits under Poplar block plantation

Transparent plastic low tunnel during 2020-21

Black plastic low tunnel during 2019-20

Removal of sheets during daytime

Plate 5: Growth under plastic tunnel during month of Dec-Jan

determine seed yield of cucurbits. Seed weight was recorded after proper removal of pulp from seeds by cleaning with water and then dried under shade.

3.5 Tree growth parameters

Growth parameters (tree height, tree diameter, crown spread and leaf fall pattern) of trees were measured. The basic methodology followed is explained below.

a. Tree height (m)

Tree height (from ground level to the tip of tree) was measured with the help of Ravi's multimeter. The height was recorded after every six months in two consecutive years (5 and 6 years age) of both plantations. Leafless period of trees gave more accurate readings with minimum error.

b. Diameter at breast height (cm)

Using measuring tape, diameter over bark was measured at 1.37 m (breast height) above ground level. At first, circumference of tree was measured in centimeters (cm) which was converted to diameter by using formula as:

$$\text{Circumference} = 2\pi r = \pi d$$

In case of knots and other such abnormalities, measurements were made at clear and clean points or slightly above or lower points.

c. Crown spread (m^2)

With the help of tape, crown spread was measured in meters from tree trunk in horizontal (E-W) and vertical (N-S) direction. The readings were taken by holding the tape beneath the canopy from one edge to the opposite edge of the branches. In this way two readings were taken which were averaged to get crown spread.

$$\text{Widest diameter (D)} = \frac{D1 + D2}{2}$$

$$CS = \Pi D^2/4$$

Where,

CS = crown spread

D1 = Crown spread in north- south direction (m)

D2 = Crown spread in east-west direction (m)

d. Leaf fall pattern

As poplar is deciduous in nature, the percentage of gradual leaf fall to frequent leaf fall was observed visually at fortnightly interval from September to January. The time period between the beginning of leaf fall and new emergence of leaves was also observed.

e. Leaf area index (LAI)

It is the ratio of the leaf area to the ground area. The instrument i.e. Digital plant canopy analyser was used to record LAI. A fish eye optical sensor was used to take above and below canopy measurements. It was used to measure the canopy light interception at 5 angles that gave LAI by using a model of radioactive transfer in vegetative canopies.

3.6 Micrometeorological observations

a. Maximum and minimum temperature (°C)

Air temperature under plantations was measured by means of thermometers kept in wood box called Stevenson screen. It is fixed at height of about 1.22 m above ground level. Maximum and minimum thermometers lie in horizontal position on the upper and lower sides of wooden box. Mercury-in-glass thermometer was used for measuring maximum temperature whereas a minimum temperature reading was taken from alcohol-in-glass thermometer. The temperature readings were recorded twice a day (8:30 am and 2:30 pm), during the cropping season. The monthly mean was worked out from the data recorded daily. For controlled condition, data was recorded from meteorological observatory stationed in PAU, Ludhiana.

b. Relative humidity (%)

The Stevenson screen also contain two other thermometers called dry bulb and wet bulb thermometers placed in vertical direction. Dry bulb temperature was measured through mercury-in-glass thermometer called dry bulb thermometer. The bulb of wet bulb thermometer acts as evaporating surface and was kept moist by covering it with muslin cloth and dipped in distilled water. The temperature readings of both wet and dry bulb thermometers were used to compute relative humidity under poplar plantation. For controlled conditions, data for relative humidity was taken from meteorological observatory. The readings were taken twice a day at 11:00 am and 3:00 pm and the average after fifteen days was worked out.

c. Photosynthetically Active Radiation (PAR µmol/m^2/s)

PAR was measured on a sunny day between 12:00-2:00 pm. The readings were taken randomly at different positions with the help of quantum sensor under the tree-crop combination and open conditions at an interval of 15 days.

3.7 Soil parameters

Soil samples were collected randomly with the help of post hole auger at 0-15 cm depth separately from each environments *i.e.* under tree-crop combination as well as open conditions. Collected samples were air dried, thoroughly crushed and passed through 2mm sieve and finally analysed for soil pH, EC, OC and N, P, K.

a. Available nitrogen

The method used to estimate available nitrogen was given by Subbiah and Asija (1956). At first, 5 g of soil was weighed and dissolved in distilled water. Then the weighed soil was added to distillation flask and 25 ml of 0.32 percent $KMnO_4$ and 25 ml of 2.5 percent NaOH were added to the distillation flask and cork was fitted immediately. Thereafter, 10 ml N/50 H_2SO_4 was put in a conical flask and 2-3 drops of methyl red indicator was added to it. After completing the set up, hot plate was switched on and 25-30 ml distillate was collected in the conical flask containing N/50 H_2SO_4. The excess of H_2SO_4 collected was titrated against N/50 NaOH. The change of colour from pink to yellow was observed as endpoint.

$$\text{Available nitrogen (\%)} = \frac{(10 - A) \times 0.00028 \times 100}{\text{Weight of soil}}$$

Where,

A = Volume of 0.02N NaOH used

ppm of available N in soil = available nitrogen (%) × 10,000

Available nitrogen (kg/ha) = ppm × 2.24

b. Available phosphorus (kg/ha)

Olsen method (Olsen *et al* 1954) was used to determine available phosphorus. One gram of soil was weighed and taken in a 150 ml conical flask. A pinch of Darco-G 60 and 20 ml of 0.5 N sodium bicarbonate was added in it. The contents were mixed well for thirty minutes and filtered to obtain clear filterate. In a 25ml volumetric flask, 5 ml of filterate was taken and then 5ml of ammonium molybdate was added and in order to remove evolved CO_2, mixture was shaken thoroughly. To the prepared content, 10 ml of distilled water was added followed by 1 ml of working solution of stannous chloride. The final volume made was 25 ml by using distilled water. The contents were mixed thoroughly and the intensity of blue colour was measured in colorimeter after five minutes at 660nm.

ppm of available phosphorus in soil = A × Total dilution

Where,

A = concentration of P read from the standard curve

Available phosphorus (kg/ha) = ppm × 2.24

c. Available Potassium (kg/ha)

The method used to determine available potassium was Merwin and Peech method (Merwin and Peech 1951). At first 5 g of soil was taken in a 150 ml conical flask. To this, 25 ml of neutral 1 N ammonium acetate solution was added and the contents were shaken for five minutes on electric shaker. Then, the contents were filtered and the filterate was fed to the atomizer of the flame photometer. Finally the readings were observed and expressed in ppm.

Where,

ppm of available potassium in soil = Y × Total dilution

Y = ppm as read from the standard curve

Available potassium (kg/ha) = ppm × 2.24

d. Soil pH

With the help of digital pH meter, soil pH was measured of both the samples taken before transplanting and after harvesting, by making 1:2 soil water suspension.

e. Electrical conductivity (dS/m)

Electrical conductivity meter was used to measure EC of soil by making 1:2 soil water suspension.

f. Soil organic carbon (%)

Rapid titration method was used to determine soil organic carbon of the samples taken before transplanting and after harvesting (Walkley and Black 1934).

g. Soil texture

The texture of soil from experimental site was determined in the laboratory by specific gravity hydrometer method. On the basis of hydrometer analysis, soil was categorized into one of the class *i.e.* sand, silt and clay.

3.8 Crop Parameters

Various important parameters for crop were recorded as explained below:

1. Vine Length (cm)

Vine length was measured at first harvesting on five vines from each treatment and averaged.

2. Number of primary branches

It was measured as branches arose from the main stem at first harvesting on vines and averaged.

3. Days to 50 % flowering

The number of days from transplanting to the appearance of pistillate flowers was recorded on 50 % plants.

4. Polar diameter of fruit (cm)

Using digital calliper, it was measured as the distance from blossom end to the stem end of five randomly individual plants per treatment and averaged.

5. Equatorial diameter of fruit (cm)

The horizontal distance between two distal ends of fruit was measured using digital calliper of five randomly individual plants per treatment and averaged.

6. Fruit shape index

It was calculated as the ratio of polar diameter to equatorial diameter of fruits and averaged.

7. Fruit skin colour pattern

It was recorded as uniform, mottled or striped colour at marketable stage of the fruit.

8. Days to harvest (marketable stage)

Numbers of days from date of transplanting to the first harvest of the fruits were recorded.

9. Fruit yield per plot (kg)

It was recorded as net fruit yield of plants per plot.

10. Seed yield per plot (g)

It was recorded as net seed yield of fruits per plot.

All the crop parameters were recorded at harvesting stage. The data related to one treatment under sub-plot i.e. mid-March planting time was not analysed as the crop didn't bear fruits due to shading effect of poplar canopy by March onwards. Pumpkins and squashes are warm season crop that requires abundant sunshine for its proper growth and development.

Therefore, the total treatments reduced to 18 (2 environments × 3 planting times × 3 varieties) and total number of combinations became 54 (18 × 3 replications).

3.9 Statistical analysis

The present study was subjected to statistical analysis by following the procedure given by Panse and Sukhatme (1989). The critical difference was calculated whenever the experimental effects exhibited significance at 5 percent level of probability.

Analysis of Variance

Source of variation	Degree of freedom
Replication	2
Environment	1
Error a	2
Planting time	2
Environment x Planting time	2
Error b	8
Varieties	2
Environment x Varieties	2
Planting time x Varieties	4
Environment x Planting time x Varieties	4
Error c	24
Total	53

CHAPTER IV

RESULTS AND DISCUSSION

The present study entitled "Evaluation of growth and yield performance of *Cucurbita* spp. planted at different times under poplar block plantation" was conducted for two consecutive years (2019-20 and 2020-21) in the experimental area of Department of Forestry & Natural resources, College of Horticulture & Forestry, Punjab Agricultural University, Ludhiana. The results obtained for the different parameters under agri-silviculture system are presented under the following sub headings:

4.1 Meteorological parameters

4.2 Tree parameters

4.3 Crop growth parameters

4.4 Crop yield and yield attributing parameters

4.5 Soil parameters

4.1 Meteorological parameters

Minimum temperature, maximum temperature, relative humidity and PAR were recorded both under the poplar canopy and open conditions. These aspects bring microclimatic modifications that have a crucial role in growth and production of crop plants.

4.1.1 Temperature

The temperature variation was observed both under poplar and open conditions during the growth period of cucurbit crops for the two consecutive years. The temperature data recorded is presented in Fig. 4.1 and 4.2. The maximum and minimum temperature under poplar plantation was lower than the open and on annual basis it was recorded higher during 2020-21 and lower during 2019-20. Throughout the cucurbit crop growth period of (2019-20), the maximum temperature range under poplar canopy varied from 15.4 to 34.6 °C while it varied from 16.6 to 36.9 °C under open conditions. Maximum temperature range in the successive year (2020-21) was higher than the previous year under poplar canopy (16.1 to 35.1°C) and it was 16.9 to 36.3 °C under open conditions. The minimum temperature range was also higher during 2020-21 than 2019-20. Under poplar canopy, minimum temperature ranged between 6.2 to 21.8 °C while, under open conditions it was higher and varied from 7.1 to 22.6 °C. In 2019-20, the minimum temperature varied from 6.4 to 21.4 °C under poplar canopy and 7.5 to 22.3 °C under open conditions.

Singh *et al* (2019a) also reported similar results as above and revealed agroforestry systems as an adaptive strategy to protect crop plants from extremes in microclimate.

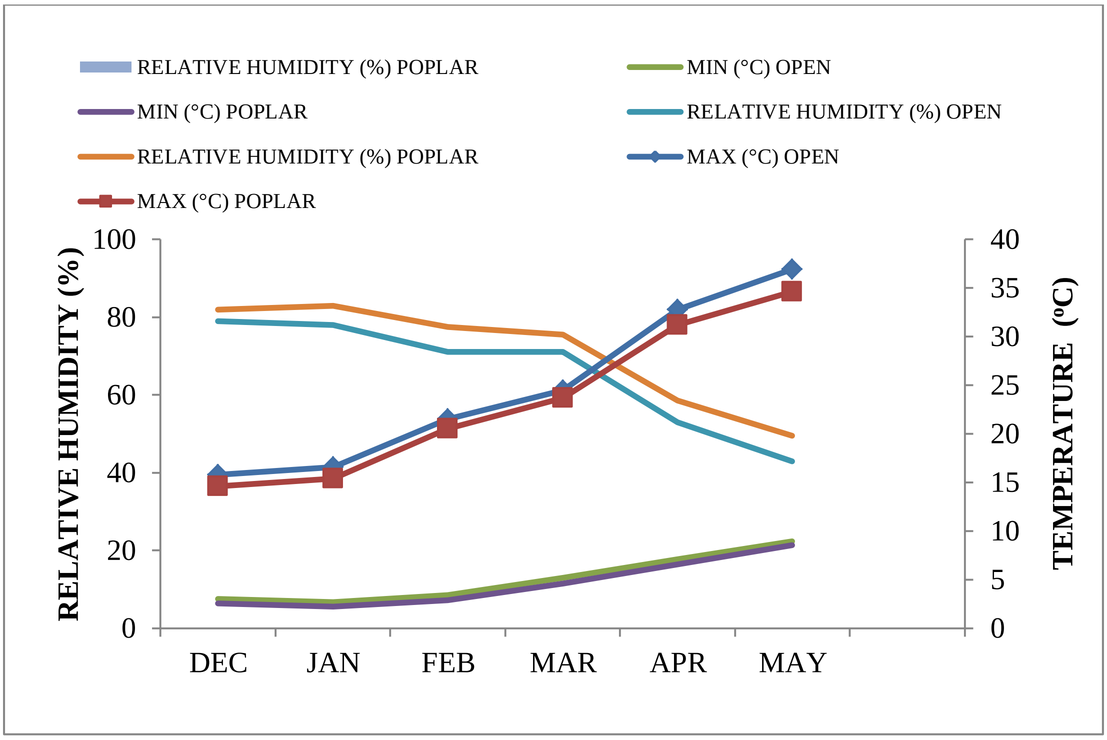


Fig. 4.1: Monthly variation in temperature and relative humidity under poplar and open during growing season of cucurbits (2019-20)

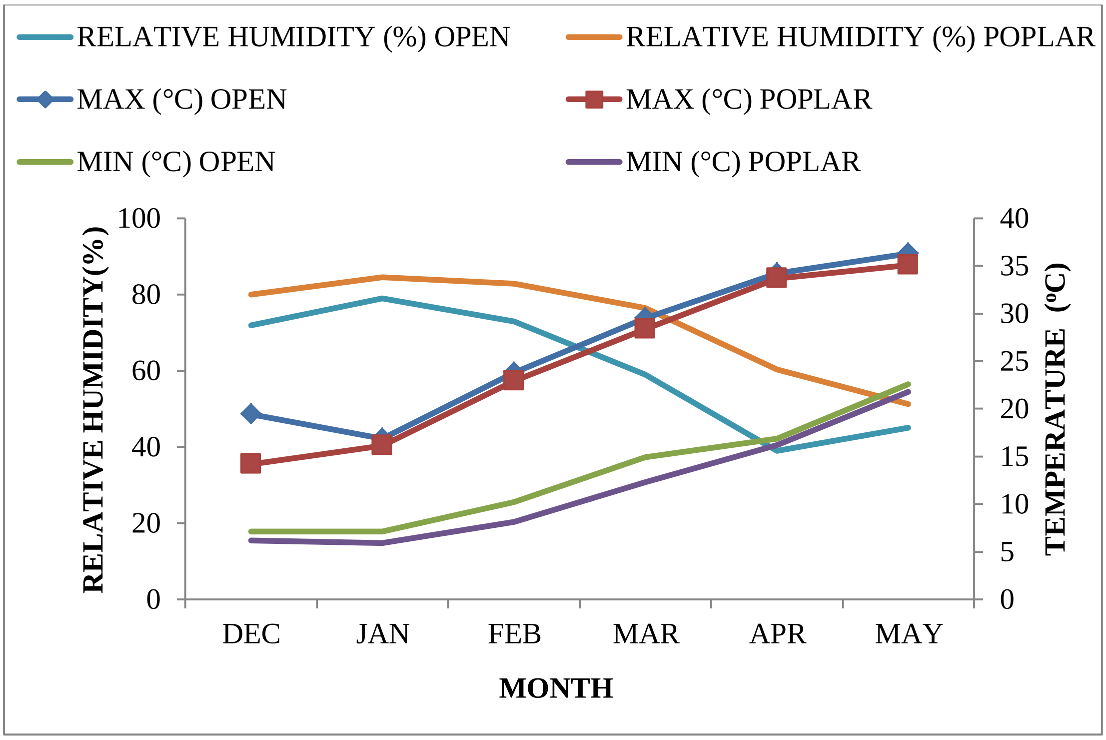


Fig. 4.2: Monthly variation in temperature and relative humidity under poplar and open during growing season of cucurbits (2020-21)

4.1.2 Relative Humidity

Unlike maximum and minimum temperature, the relative humidity was more beneath poplar canopy than open condition. In the first year growth period of cucurbit crop (2019-20), the maximum relative humidity was in December and it was 82 % under poplar canopy and 79 % under open condition. The minimum was recorded in May (49.5 %) under poplar and 43 % under open condition. The successive year (2020-21) recorded the maximum relative humidity in January and it was 84 % under poplar and 79 % under open condition (Fig. 4.3). Singh *et al* (2019a) also revealed a similar pattern of higher relative humidity under poplar canopy than the open conditions.

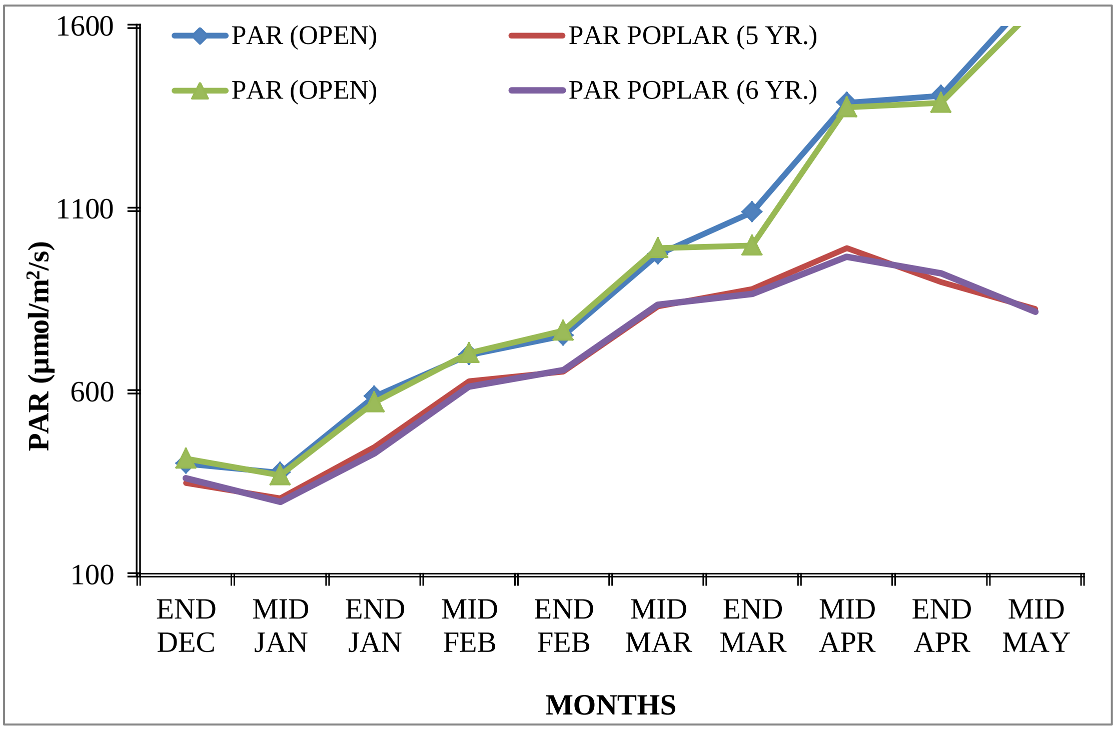


Fig. 4.3: Monthly variation of PAR (µmol/m^2/s) under poplar and open conditions

4.1.3 Photosynthetic active radiation (PAR)

Photosynthetic active radiation was higher under open conditions than under poplar plantation (Fig. 4.3). During the leafless period of poplar, there was relatively less difference in PAR recorded under poplar and open conditions. As the flushing of shoots starts in March and reach full-fledged canopy in May, the difference became more prominent between poplar and open conditions. Under poplar plantation, value of PAR started increasing from January (309.0 µmol/m^2/s) till first fortnight of April (901.2 µmol/m^2/s) and then it declined. Under open conditions, PAR continued to increase from sowing till harvesting and it ranged from 403.7 µmol/m^2/s (mid-January) to 1692.4µmol/m^2/s (mid-May). Similar trend was observed during the growth period of intercultivated and sole cucurbits for the successive year. The availability of PAR changes the microclimate of the area which further affects the eco-physiological parameters and ultimately the yield (Sangwan *et al* 2016).

4.2 Tree parameters

Tree growth is a function of various locality factors and genotype acting simultaneously. Height and diameter are important components of tree volume. In addition, heights of trees are required to find out productive capacity of site. In the present study, tree height (m), diameter at breast height (cm), crown spread (m^2), leaf fall (%) and leaf area index was evaluated in the poplar block plantation. These growth parameters were recorded at six months interval in May and December during the two consecutive years, 2019-20 and 2020-21. The tree age in the respective years was 5 and 6 years. These are discussed as follows:

4.2.1 Tree height

The average tree height of 5 years old poplars was 15.1 m and it varied from 14.3 to 16.4 m. After one year, its mean height increased to 17.6 m with range from 14.8 to 19.1 m.

4.2.2 Diameter at breast height

The diameter increment was recorded for both the years, average diameter of 6 year old poplars was 18.4 cm and it varied from 17.5 to 19.7 cm.

4.2.3 Crown spread

It was recorded at full blooming stage in the month of May to avoid any kind of error. It was observed that average crown spread of 5 and 6 years old poplar was 17.3 m^2 and 23.5 m^2, respectively.

Growth parameters of trees *viz.* height, diameter and crown spread increased with increase in age of trees (5^{th} to 6^{th} year). The growth of poplar under agroforestry system is benefitted from the applied inputs (cultural practices, irrigation and fertilization) to intercrop. Rani *et al* (2015) reported 11.5 % and 8.47 % increase in tree height and diameter in flowers annuals intercropping. Chaudhry *et al* (2003) and Verma (2008) also reported the better growth of poplar under agroforestry system than the growth of trees in block plantation without intercropping.

4.2.4 Leaf fall pattern

Poplar being a winter deciduous tree helps to grow winter crops under block/boundary plantation of poplar. The leaf fall pattern was recorded from September to January at an interval of 15 days. The visual representation of leaf fall pattern is presented in Plate 6. It was noticed that leaf fall started progressively from September-October with frequent fall during November-December and maximum in the last two weeks of December. The trees become completely leafless by January. Bhardwaj *et al* (2021) recorded the similar

Mid –September **End -September**

Mid -October **End -October**

Mid -November **End -November**

Mid -December

End -December

Mid -January

End-January

Plate 6: Leaf fall pattern of *Populus deltoides* during growing season of interplanted cucurbits

leaf fall pattern under block plantation of poplar. Kumar *et al* (2001) described slow decomposition of poplar leaf litter and its impact on growth of intercrops.

4.2.5 Leaf area index (LAI)

Leaf area index is a key parameter to study many physiological processes associated with trees. It is highly correlated with photosynthesis, transpiration and productivity of tree-crop mixtures. In agroforestry, LAI is influenced by factors like phenology, climate and interaction between trees and crops (Taugourdeau *et al* 2014). It was recorded during the growing season of intercropped cucurbits (from December to May).Minimum LAI was recorded from mid-December to end-February. It gradually increases from March as poplar starts bearing new flush of leaves. Maximum LAI was observed in the month of May when poplar attain full-fledged canopy. As age of trees increases from 5 to 6 years, LAI also increases (Fig. 4.4). It is regulated in agroforestry by tending operations like pruning and lopping to have a clear bole and to minimise the shade on intercultivated crops. Jyoti *et al* (2019) also recorded the similar pattern of LAI in poplar canopy.

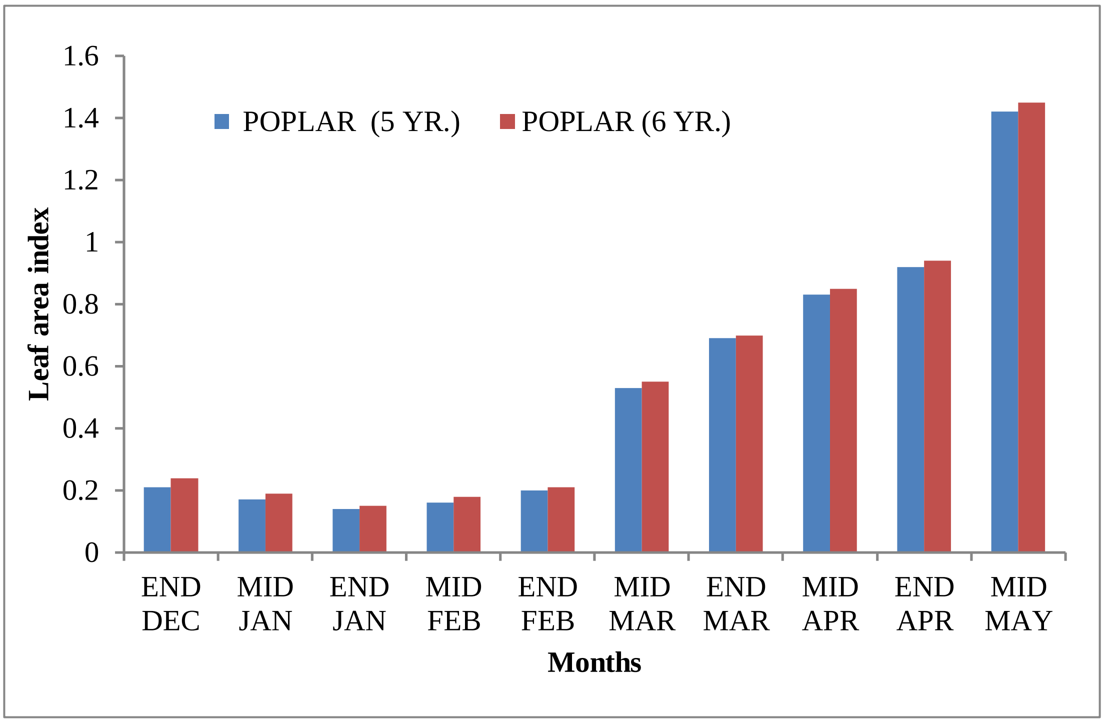


Fig. 4.4: LAI of poplar during the growing seasons (2019-20 & 2020-21) of cucurbits intercrop

4.3 Crop growth parameters

4.3.1 Vine length (cm)

Vine length is an important attribute related to growth and development of crop. It reflects the yield potential of cucurbits. Table 4.1 presented the data on vine length taken during the first harvest of the cucurbit crops. There were no significant differences in vine length between poplar and open environment. It might be due to less microclimatic variations between the two environments during the growth period (December-February) of cucurbit crops.

Planting time is known to play a major role in cucurbits for successful production with enhanced productivity via affecting sex expression (Maragal *et al* 2018). The crop planted in mid-January recorded significantly higher vine length of 182.09 cm than mid-December (121.31 cm) and mid-February (100.65 cm) planted crops The complete leaf shedding of poplar tree by mid-January might be the reason behind it. The use of plastic tunnels during adverse weather conditions in the month of December and January also favored the crop growth transplanted during these two months. As cucurbits are very sensitive to cold temperature and plants will exhibit injury from even a slight frost. Bhatt *et al* (2016) also reported similar results for summer squash. It was reported that summer squash transplanted on 15th January was found to be best among three transplanting dates with respect to plant growth characters, total yield and net return. Nesmith (1993) also reported that if transplants were delayed past the optimum in which they are making active growth after transplanting would be affected.

Table 4.1: Crop growth parameters of cucurbit varieties planted at three different times under poplar and open during 2019-20 (Y1) and 2020-21 (Y2)

Treatments		Vine length(cm)			Number of primary branches		
		Y1	Y2	Mean	Y1	Y2	Mean
Environment	Poplar	112.99	111.86	112.42	2.78	2.76	2.77
	Open	121.19	119.69	120.44	3.42	3.35	3.38
	CD (0.05)	NS	NS		NS	NS	
Time of planting	Mid Dec	122.03	120.6	121.31	3.34	3.23	3.28
	Mid Jan	128.59	127.6	128.09	3.56	3.44	3.5
	Mid Feb	100.65	99.13	99.89	2.4	2.47	2.43
	CD (0.05)	7.34	5.65		0.323	0.339	
Varieties	PCK-1	84.49	83.05	83.77	2.87	2.85	2.86
	PPH-1	192.15	190.43	191.29	3.8	3.71	3.75
	PMK-1	74.62	73.86	74.24	2.63	2.61	2.62
	CD (0.05)	6.55	8.43		0.207	0.242	

Due to variation in growth habit, the vine length of bush type cucurbit varieties, PCK-1 and PAU-Magaz kadoo-1 were 83.77 cm and 74.24 cm, respectively. The medium-vine type hybrid cucurbit, PPH-1 recorded longest vine length of 191.29 cm because of its sprawling vines. Kaur *et al* (2017) and Kim *et al* (2010) also reported a varied range of genetic differences for vine length among various cucurbit varieties. Bush types are preferred over vine types to accommodate more number of plants, early flowering, high yield and mechanical weed control (Dhatt *et al* 2020). The growth habits of these three varieties are presented in Plate 8. A similar pattern was also observed in successive year w.r.t time of planting and varieties. Generally, vine length of cucurbit crop was observed to be lower under 6 year old poplar than 5 year old poplar due to changes in tree crop interactions. With the increase in age of trees, the larger tree canopy may decrease the radiation available to the intercultivated crop by intercepting part of it.

4.3.2 Number of primary branches

Number of primary branches per vine is a vital parameter, which represent higher reproductive nodes. The number of primary branches was significantly influenced by time of planting and varieties (Table 4.1).With regards to time of planting, cucurbits planted in mid-January showed the highest number of primary branches (3.5), at par with mid-December planted crops (3.28) and least in mid-February (2.43). The difference might be due to the fact that lower temperature at growing period leads to reduced physiological processes like transpiration and respiration that resulted in reduced water loss and increased net accumulation of photosynthates (Maragal *et al* 2018).

The number of primary branches varied with different cucurbit varieties. The difference also depended upon the vine type and vine length of varieties. PPH-1 hybrid being trailing in nature recorded 3.86 number of primary branches followed by bushy type varieties, PCK-1 (2.86) and PAU-Magaz Kadoo-1 (2.62). The variation in growth of different cucurbit varieties might be due to different tolerance capacity to competition for resources such as light, moisture and nutrients. The number of primary branches was significantly more in sole crop (3.42 and 3.35) than intercropping with poplar (2.78 and 2.76) during both the years.

4.3.3 Days to 50 % flowering

Number of days to 50 % flowering is an important indicator of the crop maturity. It depends upon the cultivar, flower sex and environment. Cucurbit varieties with early flowering are in general early in fruiting to reach marketable stage. The data pertaining to number of days to 50 % flowering is presented in Table 4.2 which showed that number of days to 50 % flowering was found significant for environment, planting times and varieties during both the years.

Table 4.2: Number of days to 50 % flowering and harvesting of cucurbit varieties planted at three different times under poplar and open during 2019-20 (Y1) and 2020-21 (Y2)

Treatments		Days to 50 % flowering		
		Y1	**Y2**	**Mean**
Environment	Poplar	54.59	55.37	54.98
	Open	52.55	51.62	52.08
	CD (0.05)	0.57	1.61	
Time of planting	Mid Dec	57.27	56.61	56.94
	Mid Jan	52.16	52.5	52.33
	Mid Feb	51.27	51.38	51.32
	CD (0.05)	1.29	0.7	
Varieties	PCK-1	47.88	47.44	47.66
	PPH-1	54.27	54.33	54.3
	PMK-1	58.55	58.72	58.63
	CD (0.05)	0.82	0.86	

Among the planting times, mid-December planted crop took the maximum number of days to 50% flowering (57.27 and 56.61) followed by mid- January (52.16 and 52.5) whereas mid-February planted crop took the minimum number of days (51.27 and 51.38) to 50% flowering. The gradual increase of temperature from February onwards resulted in taking least days to 50% flowering in mid-February planted cucurbits.

Among varieties, PCK-1 is characterized by early flowering and high ratio of pistillate to staminate flowers, so it took minimum number of days to 50 % flowering (47.88 and 47.44) and followed by PPH-1 hybrid (54.27 and 54.33). The maximum number of days to 50 % flowering was taken by variety PAU-Magaz kadoo-1 (58.55 and 58.72) during both years. Visual representation of days to 50 % flowering is shown in Plate 8. The variation in environments showed that it took maximum number of days to 50 % flowering under poplar (54.59 and 55.37) than open conditions (52.55 and 55.37). Nesmith and Hoogenboom (1994) reported that thermal variations strongly contributed to differences in days to flowering for summer squash under diverse environment. Kim *et al* (2010) also reported a wide variation in days to flowering in various squash germplasm.

PCK-1 (bush type)

PPH-1 (vine type)

PAU MK-1 (bush type)

Plate 7: Growth habit of different cucurbits

Plate 8: a) Days to 50% Flowering; b) Staminate flower; c) Pistillate flower; d) Ovary developed into fruit

4.3.4 Days to first harvest

The data related to number of days to harvesting for cucurbit varieties planted under poplar and open at different times is presented in Table 4.3. During both the experimental years, cucurbit crop intercropped with poplar took more number of days to harvesting (89.63 and 90.25) as compared to sole crop (86.51 and 86.85). Significant differences were recorded among times of planting with maximum number of days to harvesting in early planted crops (92.22 and 92.27) than late planted crops (84.89 and 85.56) during both the years. It may be explained as a response to the seasonal variation of environmental factors such as photoperiod, air temperature and light intensity, which increased as the summer approached, thus accelerating the end of vegetative growth in the case of late planted crops (Khokhar 2008).

Among varieties, wide differences in days to harvesting were found as two varieties (PCK-1 and PPH-1) were harvested at immature stage for vegetable purposes when it reached a marketable stage and PAU-Magaz kadoo-1 was kept to mature fully for snack seed purposes. PCK-1 (80.27 and 80.66) and PPH-1 (90.22 and 91.66) had minimum number of days to harvesting while, PAU-Magaz kadoo-1 took maximum number of days to harvesting (93.72 and 93.83).

Table 4.3: Number of days to harvesting of cucurbit varieties planted at different times under poplar and open during 2019-20 (Y1) and 2020-21 (Y2)

Treatments		**Days to harvesting**		
		Y1	**Y2**	**Mean**
Environment	Poplar	89.63	90.25	89.94
	Open	86.51	86.85	86.68
	CD (0.05)	0.99	0.15	
Time of planting	Mid Dec	92.22	92.27	92.24
	Mid Jan	87.11	87.83	87.47
	Mid Feb	84.89	85.56	85.22
	CD (0.05)	1.84	1.24	
Varieties	PCK-1	80.27	80.66	80.46
	PPH-1	90.22	91.16	90.69
	PMK-1	93.72	93.83	93.77
	CD (0.05)	1.10	1.42	

4.4 Crop yield and yield attributing parameters

4.4.1 Polar diameter of fruit

Data pertaining to polar diameter is presented in Table 4.4. There was no significant difference in polar diameter with respect to environment during both years and but significant for planting time and mid-January planted crops recorded highest polar diameter (80.83, 70.66) than mid-December and mid-February planted crops during the two years.

There was a significant difference in polar diameter among varieties due to its varied fruit-size at harvesting stage. Polar diameter of all the three varieties, PCK-1 (50.08, 45.19 cm), PPH-1 (90.39, 80.87 cm) and PMK-1 (92.8, 86.01 cm) were recorded during first and second year. It decreases with the increase in age of poplar. Polar diameter of fruit varies with varieties and depends upon the shape of the fruit. It is one of the parameter to determine fruit shape index (FSI) of cucurbits. In our study, wide variations were observed in polar diameter than that reported by Aruah *et al* (2010) in *Cucurbita* species i.e. 30-61 cm.

4.4.2 Equatorial diameter

Equatorial diameter is an important parameter related with girth of the fruit. It is the second component after polar diameter to determine fruit shape index. It is inferred from the Table 4.4 that equatorial diameter shows significant difference w.r.t environment, planting times and varieties during both years. Among planting times, equatorial diameter was recorded highest in mid-January (85.63, 83.99 cm) followed by mid-December and mid-February planted crop.

Due to difference in fruit size and growth habit of cucurbits, there was a wide variation in equatorial diameter. Equatorial diameter of fruits of PCK -1 (58.93, 58.77 cm), PPH-1 (91.17, 89.52cm) and PAU-Magaz kadoo-1 (92.89, 90.25 cm) were recorded during the two experimental years. Kaur *et al* (2018) also observed significant differences among various generations of cucurbits for parameters like vine length, days to 50% flowering, polar diameter, equatorial diameter and fruit yield.

4.4.3 Fruit Shape Index (FSI)

Fruit shape index (polar and equatorial diameter ratio) determines the shape of fruit. The ratio of 1.00 shows complete roundness, more than 1.00 towards elliptical and less than 1.00 towards flat shape of the fruit. The data related to fruit shape index is presented in Table 4.4 which showed that it was found non-significant for environment and planting times but significant for varieties for both the years. PCK-1 being disc-shaped recorded fruit shape index of 0.85 and 0.76 during the two experimental years. FSI of remaining varieties, PPH-1 (0.98 and 0.89), PAU-Magaz kadoo-1 (0.99 and 0.94) were recorded during the two experimental years. Kaur *et al* (2017) also reported a wide variation in fruit shape index of different pumpkin varieties ranging from 0.48 to 1.75.

Table 4.4: Polar diameter (cm), equatorial diameter (cm) and fruit shape index of three cucurbit varieties planted at different times under poplar and open during 2019-20 (Y1) and 2020-21 (Y2)

Treatment		Polar diameter (cm)			Equatorial diameter (cm)			Fruit shape index		
		Y1	**Y2**	**Mean**	**Y1**	**Y2**	**Mean**	**Y1**	**Y2**	**Mean**
Environment	Poplar	76.71	70.35	73.53	80.1	78.54	79.32	0.94	0.87	0.9
	Open	78.81	71.03	74.92	81.9	80.49	81.19	0.95	0.86	0.9
	CD (0.05)	NS	NS		1.4	1.19		NS	NS	
Time of planting	Mid Dec	76.77	70.25	73.51	79.19	77.17	78.18	0.93	0.84	0.88
	Mid Jan	80.83	73.66	77.24	85.63	83.99	84.81	0.94	0.85	0.89
	Mid Feb	75.67	68.15	71.91	78.17	77.38	77.77	0.93	0.83	0.88
	CD (0.05)	2.36	2.2		2.23	2.28		NS	NS	
Varieties	PCK-1	50.08	45.19	47.63	58.93	58.77	58.85	0.85	0.76	0.80
	PPH-1	90.39	80.87	85.63	91.17	89.52	90.34	0.98	0.89	0.93
	PMK-1	92.8	86.01	89.40	92.89	90.25	91.57	0.99	0.94	0.96
	CD (0.05)	1.95	1.67		1.56	1.87		0.01	0.03	

4.4.4 Fruit skin colour pattern

The pictorial representation of fruit skin colour pattern at marketable stage is presented in Plate 9. There were marked variations in fruit skin colour pattern w.r.t varieties. It determines three types of patterns *viz.* uniform, mottled and stripped. PCK-1 and PPH-1 were having uniform green and mottled green colour pattern, respectively. It showed their pattern at immature stage when these two varieties were harvested for vegetable purpose. PAU-Magaz kadoo-1 was having stripped orange pattern at maturity when it was harvested for snack seeds purpose.

4.4.5 Fruit yield per plot

Fruit yield per plot reveals the net yield capacity of a variety in a given plot. In the present investigation, each plot had 20 plants of each variety. The data for fruit yield per plot of cucurbits planted at three different times under poplar and open conditions was recorded in two consecutive years (May 2019-20 and 2020-21) presented in Table 4.5. The fruit yield was significantly influenced by growing environments, time of planting and varieties during both the years. The fruit yield per plot was comparatively higher during the year 2019-20 (27.59 kg, 21.21 kg) than the next successive year (27.02 kg and 20.44 kg) under open and poplar, respectively.

Table 4.5: Fruit yield per plot of three cucurbit varieties planted at different times under poplar and open during 2019-20 (Y1) and 2020-21 (Y2)

Treatments		**Fruit yield per plot (kg/plot)**		
		Y1	**Y2**	**Mean**
Environment	Poplar	21.21	20.44	20.82
	Open	27.59	27.02	27.30
	CD (0.05)	0.43	0.34	
Time of planting	Mid Dec	24.07	23.05	23.56
	Mid Jan	26.24	25.73	25.98
	Mid Feb	22.84	22.41	22.62
	CD (0.05)	0.44	0.22	
Varieties	PCK-1	13.92	13.52	13.72
	PPH-1	32.59	31.76	32.17
	PMK-1	26.64	25.9	26.27
	CD (0.05)	0.4	0.31	

PCK-1 (Uniform green)

PPH-1 (Mottled green)

PAU MK-1 (Stripped oragne)

Plate 9: Fruit skin colour pattern at marketable stage

The mid-January (26.24 kg, 25.73 kg) planted crop gave significantly higher fruit yield per plot than the mid-December (24.07 kg, 23.05 kg) and mid-February (22.84, 22.41 kg) planted crop. The reduction in fruit yield of mid-February planted crop might be due to the gradual development of new flush of leaves in poplar that reduced the photosynthetically active radiations intercepted by intercultivated cucurbits and thus affecting its growth and development. Wien *et al* (2002) reported that a delay in fruit set by high temperatures may in turn results in increased vegetative growth and shading of developing pistillate flowers.

All three varieties showed good yield based upon their fruit size and growth habit. PPH-1 hybrid, having heavier fruit weight recorded highest fruit yield (32.59 kg, 31.76 kg) per plot followed by PAU-Magaz kadoo-1 (26.64 kg, 25.9 kg) and PCK-1 (13.92 kg, 13.52 kg) during the two experimental years. However, more number of female flowers per plant in PCK-1 gave highest number of fruits per harvest than the other two varieties. The results showed wide variation for fruit yield per plot; therefore can be consumed as vegetable (PPH-1 and PCK-1) as well as snack seed pumpkin (PAU Magaz kadoo-1).

4.4.6 Fruit yield per hectare

Fruit yield per hectare determines the total economic yield potential of a variety. It is inferred from the Table 4.6 that fruit yield per hectare follows the similar trend of fruit yield per plot w.r.t. environment, planting times and varieties, as the latter was used to calculate the yield in tonnes per hectare. The fruit yield per hectare was comparatively higher during the year 2019-20 (36.7, 28.2 t/ha) than the next successive year (36.02, 27.24 t/ha) under open and poplar. With the increase in age of poplar the availability of light, moisture and nutrients decreases for the growth and development of the intercrop.

During both years, mid-January planted crop had the highest fruit yield (34.98, 34.3 t/ha) followed by mid-December (32.1, 30.72 t/ha) and mid-February planted crop (30.45, 29.88 t/ha). The results are in accordance with Bhatt *et al* (2016) that summer squash transplanted in mid-January using low plastic tunnel gave good fruit yield than the other planting times.

Based upon its varied fruit size, all the three varieties, *viz.* PPH-1, PAU Magaz kadoo-1 and PCK-1 gave a good yield of 43.45, 42.34 t/ha; 35.52, 34.53 t/ha and 18.57, 18.03 t/ha during first and second year, respectively. The results indicated that there was a large variation for fruit yield in cucurbit varieties. It might be due to variations in cucurbits for attributes like female to male flower ratio, pollen production, successful pollination, fruit set and number of fruits per plant. Kaur *et al* (2018) also reported a wide fruit yield variation in pumpkin genotypes ranging from 14.2 to 39.1t/ha.

Table 4.6: Fruit yield of cucurbit varieties planted at different times under poplar and open during 2019-20 (Y1) and 2020-21 (Y2)

Treatments		Fruit yield (t/ha)		
		Y1	**Y2**	**Mean**
Environment	Poplar	28.2	27.24	27.72
	Open	36.7	36.02	36.36
	CD (0.05)	0.58	0.47	
Time of planting	Mid Dec	32.1	30.72	31.41
	Mid Jan	34.98	34.3	34.64
	Mid Feb	30.45	29.88	30.165
	CD (0.05)	0.6	0.3	
Varieties	PCK-1	18.57	18.03	18.3
	PPH-1	43.45	42.34	42.89
	PMK-1	35.52	34.53	35.02
	CD (0.05)	0.53	0.41	

A considerable reduction in fruit yield (t/ha) was found under the poplar canopy as compared to the open conditions (Table 4.7). The difference between two growing environments resulted mainly due to the effect of competition for light, nutrients and moisture under poplar plantation. It was noticed that for all the three times of planting under open conditions, the three varieties gave higher fruit yield than the crop planted under poplar canopy. The percentage reduction in yield under five year old canopy recorded was 21.97 % while, under six year old canopy it increased to 24.37 %. It might be due to use of honey bee box during first experimental year for successful pollination thereby, giving more fruit yield in the first year and least percentage reduction. Moreover, with the increase in age of poplar plantation, the LAI increases and PAR decrease which leads to lower yield of intercrop. During 2019-20, the maximum reduction in fruit yield was observed in mid-February planted crop (28.2 %) whereas minimum reduction was found in mid-January planted crop (19 %). Among varieties, PAU Magaz kadoo-1 recorded the maximum fruit yield reduction of 24.2 % and 25.98 % during the two years, respectively. The minimum reduction in fruit yield under 5 and 6 year old poplar canopy was recorded in variety PCK-1 (19.3 % and 20.56 %). In the successive year, the percentage fruit yield reduction of mid-February planted crop increased from 28.2 to 31.4 % which was higher than the mid-December and mid-January planted crop.

Table 4.7: Per cent reduction in fruit yield of cucurbit varieties planted at different times under poplar canopy and open conditions during 2019-20 and2020-21

Treatments		**2019-20**			**2020-21**		
		Fruit yield (t/ha)		**% Reduction**	**Fruit yield (t/ha)**		**% Reduction**
		Poplar	**Open**		**Poplar**	**Open**	
Environment		28.28	36.74	21.97	27.24	36.02	24.37
Time of planting	Mid-December	27.87	36.33	23.29	26.46	34.99	24.39
	Mid-January	31.52	38.44	19.0	30.98	37.62	20.0
	Mid-February	25.46	35.44	28.2	24.3	35.47	31.4
Varieties	PCK-1	16.59	20.54	19.3	15.96	20.09	20.56
	PPH-1	37.61	49.28	23.7	36.40	48.29	24.63
	PMK-1	30.64	40.39	24.2	29.38	39.69	25.98

The results for the reduction in fruit yield of cucurbits under poplar are in line with the results of different intercrops grown under poplar such as wheat, soybean, turmeric, ginger, onion, flowers and various medicinal and aromatic plants. Chavan and Dhillon (2019) found yield reduction of 4 % to 46.79 % in sorghum and 3.71 % to 46.07 % in cowpea under different tree spacing of poplar during rainy season. It was reported that yield reduction under poplar ranged from 17.00 % to 36.44 % in berseem and 32.45 % to 45.59 % in wheat under 5-8 years of poplar plantation during winter season. It shows percent reduction of intercultivated crop under poplar was less during winter than rainy season. Wheat yield reduction was recorded 9.4 %, 9.9 % and 23.3 % under one year, two year and three year old poplar plantation, respectively (Ralhan *et al* 1992). In the present study, the minimum PAR was recorded in the month of December and it increased up to first fortnight of April thereafter, it started to decrease (Fig.4.3). The lesser PAR under poplar canopy affected the intercultivated cucurbits underneath by increasing number of days to flowering and harvesting and ultimately resulted in declining fruit yield (Table 4.6). In tree crop combination, crop yield is certainly affected by limited PAR but resource use efficiency is better under trees than in open conditions. Xiong *et al* (2010) also observed less soil erosion and increased land use efficiency when pumpkin was intercropped under young elm (*Ulmus* spp.) trees

The radiant energy captured by plants which is used for photosynthesis is the primary process responsible for intercultivated crop-biomass production and yield (Baig and Gill 2005). Yang *et al* (2021) reported PAR and air temperature both decreased in plots under poplar based agroforestry. The changes in microclimatic conditions and competition for resources in poplar based agroforestry systems resulted in an overall decrease in crop yield under it. The availability of PAR changes the microclimate of the understorey which further affects the eco-physiological parameters and ultimately the crop yield (Sangwan *et al* 2016). Dhillon *et al* (2010) reported the effect of modified microenvironment under poplar canopy on the physiological characteristics and yield of turmeric grown as intercrop with poplar. Gill *et al* (2009) reported that the trees plays an important role in ameliorating microenvironment by reducing air temperature, photosynthetic active radiation (PAR) and increasing relative humidity. The modification of microenvironment under agroforestry system depends upon the tree species and type of intercrop. Light is the prime factor which affects the physiological processes (photosynthesis, respiration) and are responsible for the growth and development of plants. Shade effect of trees is a major drawback under agroforestry system which results into decrease of biological productivity in plants, however the extent of drawback varies with the shade tolerance of the species. It was reported that crop development rate get shortened by shading effect nearly in direct proportion to the reduction in captivated radiations. Similar results were reported by Kobata and Takami (1986) that the climatic stress during grain filling period affected into suppression of photosynthesis that caused a major decline in grain yield of rice.

The reduction in the fruit yield of three cucurbit varieties planted at three different times under 5 and 6 year old canopy might be due to the shading effect and competition for various other resources. The ideal temperature required for good growth of cucurbits ranged from 18-30 ^{0}C. Excessive high temperature at the time of maturity (April-May) causes reduction in fruit size and storage life. PCK-1 is an early maturing variety that took minimum number of days to flowering, fruit setting and harvesting (Table 4.2 and 4.3) and therefore, performed better in terms of growth and yield contributing characters (Table 4.1, 4.4 and 4.7), thus resulted into minimum reduction in fruit yield.

The interaction data for fruit yield per hectare for two consecutive years is presented in Table 4.8. In first experimental year, mid-January planted crop recorded the highest fruit yield (38.44 t/ha) under open conditions whereas mid-February planted crop recorded the lowest fruit yield (25.46 t/ha) under poplar. Fruit yield of mid-January planted crop (31.52 t/ha) under 5 year old poplar was statistically at par with mid-February planted crop (35.44 t/ha) under open conditions. In the successive year, similar trend was observed with highest fruit yield (37.62 t/ha) in early planted crop (mid-January) under open conditions and lowest was observed in late planted crop (mid-February) under 6 year old poplar.

Table 4.8: Effect of Environment*Time of planting interaction on fruit yield (t/ha) of different cucurbit varieties

Year	Time of planting	Environment		Mean
		Poplar	Open	
2019-20	Mid-December	27.87	36.33	32.1
	Mid-January	31.52	38.44	34.98
	Mid-February	25.46	35.44	30.45
	Mean	28.28	36.73	
	CD (0.05) Environment*Time of planting = 0.84			
2020-21	Mid-December	26.46	34.99	30.72
	Mid-January	30.98	37.62	34.3
	Mid-February	24.3	35.47	29.88
	Mean	27.24	36.02	
	CD (0.05) Environment*Time of planting = 0.42			

Table 4.9: Effect of Environment*Time of planting*varieties interaction on fruit yield (t/ha) of different cucurbit varieties

Environment	Varieties	Time of planting			Mean
		Mid-December	Mid-January	Mid-February	
Poplar	PCK-1	14.58	18.8	14.5	15.96
	PPH-1	35.84	40.9	32.47	36.4
	PMK-1	28.97	33.24	25.92	29.37
	Mean	26.46	30.98	24.29	
Open	PCK-1	18.97	21.38	19.93	20.09
	PPH-1	47.71	49.78	48.38	48.62
	PMK-1	39.28	41.7	38.1	39.69
	Mean	35.32	37.62	35.47	
	CD (0.05) Environment* Time of planting *Varieties = 1.01				

The three way interaction between environments, times of planting and varieties for fruit yield was statistically significant and presented in Table 4.9. The interactive effect of various factors indicated that planting of all the three varieties during mid-January under open conditions produced significantly higher mean fruit yield (37.62 t/ha) than the other planting times under poplar and open. Delayed planting time (mid-February) resulted in lowest mean fruit yield of (24.29 t/ha) under poplar. The performance of variety PCK-1 (18.8 t/ha) planted in mid-January under poplar was statistically at par with same variety (18.97 t/ha) planted during end-December under open conditions.

4.4.7 Seed yield per plot

Seed yield per plot is also an important trait to determine seed yield potential of a variety in a given plot size. The data for seed yield per plot of cucurbits planted at three different times under poplar and open conditions was recorded in two consecutive years (May 2019-20 and 2020-21) presented in Table 4.10. The seed yield was also significantly influenced by growing environments, time of planting and varieties during both the years. The seed yield per plot was comparatively higher during the year 2019-20 (332.97, 471.48 g) than the next successive year (319.77 g and 468.14 g) under open and poplar. The mid-January (431.89, 427.19 g) planted crop gave significantly higher seed yield per plot than the mid-December (393.97, 379.25 g) and mid-February (380.52, 375.42 g) planted crop during both years.

Table 4.10: Seed yield per plot of three cucurbit varieties planted at different times under poplar and open during 2019-20 (Y1) and 2020-21 (Y2)

Treatments		**Seed yield per plot (g/plot)**		
		Y1	**Y2**	**Mean**
Environment	Poplar	332.97	319.77	326.37
	Open	471.48	468.14	469.81
	CD (0.05)	9.46	5.2	
Time of planting	Mid Dec	393.97	379.25	386.61
	Mid Jan	431.89	427.19	429.54
	Mid Feb	380.82	375.42	378.12
	CD (0.05)	3.44	3.73	
Varieties	PCK-1 (hulled)	362.71	354.21	358.46
	PPH-1 (hulled)	379.92	371.68	375.8
	PMK-1 (hulless)	464.05	455.97	460.01
	CD (0.05)	2.52	2.77	

Among varieties, the hull-less seeded pumpkin variety, PAU Magaz kadoo-1 recorded highest seed yield (464.05, 459.97 g) per plot followed by PPH-1 (379.92, 371.68 g) and PCK-1 (362.71, 354.21 g) during the two experimental years. The results showed wide variation for seed yield per plot. Seed yield depends upon various factors like genotype, fruit & seed maturity, fruit cavity, fruit size and shape. The highest seed yield in PAU-Magaz kadoo-1 was because of its larger fruit cavity and round shape, thus accommodating more number of seeds. While PCK-1 and PPH-1 are generally harvested at immature stage for vegetable purpose, PAU-Magaz kadoo-1 is harvested at mature stage, mainly for its edible hull-less seeds which is used as oil seed crop along with snack seeds rich in proteins.

4.4.8 Seed yield per hectare

It is inferred from the Table 4.11 that the seed yield follows the similar trend of fruit yield w.r.t. environment and planting times. It was recorded more under open conditions (6.27, 6.23 q/ha) than under poplar (4.42, 4.25 q/ha) during the two experimental years. Among times of planting maximum seed yield was recorded in mid-January planted crops (5.73, 5.68 q/ha) followed by mid-December (5.24, 5.04 q/ha) and mid-February (5.06, 4.99 q/ha) planted crops. The least yield in Mid-February planted crop might be due to fact that shading by trees reduces crop growth rate in direct proportion to canopy size. During February–March, poplar leaves start sprouting and by this time cucurbits slowly enters into maturity.

Table 4.11: Seed yield of cucurbit varieties planted at different times under poplar and open during 2019-20 (Y1) and 2020-21 (Y2)

Treatments		**Seed yield (q/ha)**		
		Y1	**Y2**	**Mean**
Environment	Poplar	4.42	4.25	4.335
	Open	6.27	6.23	6.25
	CD (0.05)	0.17	0.06	
Time of planting	Mid Dec	5.24	5.04	5.14
	Mid Jan	5.73	5.68	5.705
	Mid Feb	5.06	4.99	5.025
	CD (0.05)	0.05	0.05	
Varieties	PCK-1 (hulled)	4.82	4.71	4.765
	PPH-1 (hulled)	5.04	4.94	4.99
	PMK-1 (hulless)	6.17	6.07	6.12
	CD (0.05)	0.03	0.03	

However, seed yield followed the different trend of fruit yield w.r.t varieties. Highest seed yield was recorded in PAU-Magaz kadoo-1 (6.17, 6.07 q/ha) followed by PPH-1(5.04, 4.94 q/ha) and PCK-1 (4.82, 4.71 q/ha). It was mainly due to variation in genotype, fruit size, fruit cavity and numbers of seeds per fruit.

A substantial reduction in seed yield (q/ha) was found under the poplar canopy as compared to the open conditions (Table 4.12). It was noticed that that for all the three times of planting under open conditions, the three varieties gave higher seed yield than the crop planted under poplar canopy. The percentage reduction in seed yield under five year old canopy recorded was 29.6 % while, under six year old canopy it increased to 31.7 %. During 2019-20, the maximum reduction in seed yield was observed in mid-February planted crop (33.3 %) whereas minimum reduction was found in mid-January planted crop (21.5 %). Among varieties, PCK-1 recorded the maximum seed yield reduction 34.8 % and 37.08 % during the two years. The minimum reduction in seed yield was recorded in variety PMK-1 (21.8 % and 23.0 %) under 5 and 6 year old poplar canopy, respectively. In the successive year, the percentage seed yield reduction of mid-February planted crop increased from 33.3 % to 38.6 % which was higher than the mid-December and mid-January planted crop.

Table 4.12: Percent reduction in seed yield of cucurbit varieties planted at different times under poplar canopy and open conditions during 2019-20 and 2020-21

Treatments		2019-20			2020-21		
		Seed yield (q/ha)		% Reduction	Seed yield (q/ha)		% Reduction
		Poplar	Open		Poplar	Open	
Environment		4.42	6.27	29.6	4.25	6.23	31.7
Time of planting	Mid-December	4.22	6.26	32.6	4.00	6.09	34.3
	Mid-January	5.03	6.43	21.5	4.97	6.4	22.3
	Mid-February	4.0	6.13	33.3	3.80	6.19	38.6
Varieties	PCK-1 (hulled)	3.81	5.83	34.8	3.64	5.78	37.08
	PPH-1 (hulled)	3.99	6.09	34.6	3.84	6.05	36.5
	PMK-1 (hulless)	5.43	6.9	21.8	5.28	6.85	23.0

The results for the reduction in seed yield of cucurbits under poplar are in line with the results of different intercrops grown for seeds under poplar such as flowering annuals, mustards, wheat and linseed. Under four year poplar, Rani *et al* (2015) reported percentage reduction of 13.27 % in wheat grain yield; 14.9 %, 12.76 % and 5.26 % in *Dianthus barbatus*, *Verbena hybrida* and *Petunia hybrida*, respectively. Dwivedi *et al* (2007) have also reported that tree-crop interactions have adverse effect on crop productivity but the system productivity and profitability increases substantially.

Table 4.13: Effect of Time of planting*varieties interaction on seed yield (q/ha) of different cucurbit varieties

Year	Varieties	Time of planting			Mean
		Mid-December	Mid-January	Mid-February	
2019-20	PCK-1 (hulled)	4.79	5.11	4.58	4.82
	PPH-1 (hulled)	4.99	5.3	4.82	5.04
	PMK-1(hulless)	5.93	6.8	5.79	6.17
	Mean	5.24	5.73	5.06	
	CD (0.05) Time of planting *Varieties = 0.06				
2020-21	PCK-1 (hulled)	4.51	5.07	4.55	4.71
	PPH-1 (hulled)	4.83	5.28	4.72	4.94
	PMK-1(hulless)	5.79	6.7	5.71	6.07
	Mean	5.04	5.68	4.99	
	CD (0.05) Time of planting *Varieties = 0.09				

The interaction between times of planting and varieties for seed yield was found significant for two consecutive years and presented in Table 4.13. During the two experimental year, the highest seed yield was recorded in variety PAU Magaz kadoo-1 (6.8, 6.7 q/ha) planted in Mid-January while lowest was found in PCK-1 (4.58, 4.51 q/ha) planted in Mid-February. The wide variation was mainly due to difference in genotypes, fruit size, flesh thickness, fruit cavity and number of seeds per fruit.

4.5 Soil parameters

Table 4.14 and 4.15 displayed the effect of environment (poplar and open) on soil physico-chemical properties. The soil texture of the experimental area was loamy sand. The soil EC was slightly higher under poplar plantation than open experimental area, whereas pH followed the opposite trend. During both the years available N, P and K and organic carbon content was observed higher under poplar as compared to open conditions.

Dhaliwal *et al* (2020) reported significantly higher levels of available N, P and K, OC and EC in poplar based agroforestry system than the rice–wheat system. The higher level of OC under agroforestry system compared to rice-wheat system could be attributed to the regular addition of leaf litter. Gupta *et al* (2009) found an average soil organic carbon increase from 0.36 in sole crop to 0.66 percent under poplar based agroforestry system.

Likewise, Singh *et al* (2014) also observed an increase in soil organic carbon, pH, EC, available N, P, and K under poplar block plantation as compared to open farming. Maximum available N, P and K was observed in surface soil (0-15 cm) layer of profile due to addition of organic residue on it and subsequently lower values with increasing depth. Kumar *et al* (2019) also observed a similar trend of decreasing values of N, P and K with increasing soil profile depth whereas pH was lower under agroforestry system compared to open farming system. Sharma *et al* (2015) also observed lower pH under poplar based agroforestry system due to addition of litter and its decomposition and release of organic acids. Chauhan *et al* (2015) observed the soil texture under poplar plantation as sandy loam in nature.

4.5.1 Soil physical and chemical properties

Table 4.14: Soil texture of the experimental field

Soil particles	**Percentage**
Sand	82.8
Silt	11.4
Clay	5.8
Textural class	sandy loam

Table 4.15: Soil chemical properties of experimental field

Soil property		**2019-2020**	**2020-2021**	**Status**
Ph	Poplar	8.2	8.1	Alkaline
	Open	8.3	8.2	
Electrical conductivity(dS/m)	Poplar	0.24	0.26	Normal
	Open	0.19	0.21	
Organic carbon (%)	Poplar	0.43	0.45	Medium
	Open	0.22	0.24	Low
Available N (kg/ha)	Poplar	280	284	Medium
	Open	267	270	Low
Available P (kg/ha)	Poplar	27.3	28.3	High
	Open	21.0	23.0	Medium
Available K (kg/ha)	Poplar	265	270	Medium
	Open	240	251	

CHAPTER V

SUMMARY

Agroforestry is a sustainable natural resource management system that by the addition of trees on agricultural landscape provides a wide range of environmental, economic and sociocultural benefits. The systems vary extremely in their species diversity, structural complexity, productive and protective attributes and also in socioeconomic dimensions. The association between trees and crops or pastures can be sequential (temporal interaction) or simultaneous (spatial interaction) (Somarriba 1992, Torquebiau 2000). It is one of the best options for meeting day-to-day needs of the people and restoration of the degraded environment, besides providing a great opportunity for the rural development and mitigating the climate change effects (Arunachalam *et al* 2020). It assist the vulnerable populations adapt to the negative consequences of climate change. The competitive position of the agricultural sector can be improved by agroforestry (Kumar *et al* 2020a). Agroforestry contract farming comprising industry, farmers, research and financial institutions is increasing in some states of India. In some rainfed regions of India, agroforestry reduce community dependence on forests. Poplar based agroforestry constitutes the keystone of agroforestry in irrigated plains of Northern India. Poplar as an agroforestry component helps in maintaining soil health through addition of organic matter in the form of leaf litter and also helps in regulating the nutrient cycle. The farmers of Punjab, Haryana, and Uttarakhand grow intercrops with poplar based agroforestry in block plantation (Dhiman 2012b). Poplar based agroforestry systems play a major role in fulfilling the requirement of wood based industries. Poplar is a raw material for around three dozen products (Dhiman 2012a). An average farmer earns 46 per cent higher income from poplar-based agroforestry system than the rice-wheat monocropping system (Deswal *et al* 2014). With appropriate management of poplar based agroforestry system, farmers are producing an average of 100 q of wood/acre/year and yielding an income ranging from Rs 70,000 – Rs 80,000/acre/year (Gill *et al* 2015). The major intercrop in poplar based agroforestry is wheat followed by sugarcane, turmeric, sorghum, berseem fodder, maize, potato, garlic, onion as well as fruit crops also. Cucurbitaceae is a large plant family consisting of 825 species within 118 genera. Members of this family are referred to as cucurbits. Pumpkin and squashes are major vegetable and seed crops of this family. These crops have widest adaptation from temperate to tropical regions. In India, summer is grown on a limited scale in regions of Punjab, Delhi, Uttar Pradesh, Himachal Pradesh and hills of Uttarakhand. In Punjab, the total production of cucurbits is 286.46 thousand tonnes for the year 2019-2020 (Anonymous 2020a). Qualities like ease in cultivation, rapid growth, high yield and off-season nature of crop lead to higher return per unit area under small and scattered land holding, thus attracting small and marginal farmers. These are warm-season crop and require dry weather with abundant sunshine. Pumpkin and squashes are cultivated mainly for nutritional and medicinal purposes (Idouraine 1996). Considering these facts, the present investigation entitled "Evaluation of growth and yield performance of *Cucurbita* spp. planted at different times under poplar block plantation" was carried out.

The experiment was conducted in the research area of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana during *rabi* season 2019-20 and 2020-21. It involved field experiment comprised of two environments (poplar and open), three times of planting (Mid December, Mid-January and Mid-February), three cucurbit varieties with three replications in split-split plot design. Wide variation among the treatments were noticed with regard to tree parameters *viz.* tree height (m), diameter at breast height (cm), crown spread (m^2), leaf fall pattern (%) and leaf area index; crop growth and yield parameters *viz.* vine length, number of primary branches, days to 50 % flowering, days to harvesting, polar diameter, equatorial diameter, fruit shape index, fruit yield (t/ha), seed yield (q/ha); meteorological parameters *viz.* Minimum and maximum temperature, relative humidity, photosynthetic active radiation.

The outcomes of the investigation are listed below:

- Average height, diameter and crown spread of five year old poplar trees were 15.1 m, 16.6 cm and 17.3 m^2 and the corresponding values for six year old poplar increased to17.6 m, 18.4 cm and 23.5 m^2, respectively. Minimum leaf area index (LAI) was recorded in mid- January while maximum value was observed in the month of May (1.42 and1.45) during both the years.
- Leaf shedding of poplar started in the month of October and become completely leafless by the month of January.
- Throughout the cucurbit crop growth period during 2019-20, the maximum temperature range under poplar canopy varied from 15.4 to 34.6 °C while it varied from 16.6 to 36.9 °C under open conditions and the minimum temperature varied from 6.4 to 21.4 °C under poplar canopy and 7.5 to 22.3 °C under open conditions.
- The maximum value of PAR was observed in the first fortnight of April under 5 yr (993.1 µmol/m^2/s) and 6 yr (970.8 µmol/m^2/s) poplar plantation and then it started to decrease while under open conditions it was recorded higher in the month of May (1409.5 and 1390.8 µmol/m^2/s).
- Due to variation in growth habit, the vine length of bush type cucurbit varieties, PCK-1 and PAU-Magaz kadoo-1 were 83.77 cm and 74.24 cm, respectively. The medium-vine type hybrid cucurbit, PPH-1 recorded maximum vine length of 191.29 cm because of its

sprawling vines. The crop planted in mid-January recorded significantly higher vine length of 182.09 cm than mid- December (121.31 cm) and mid-February (100.65 cm) planted crops. There were no significant differences in vine length between poplar and open environment.

- The number of primary branches was significantly more in sole crop (3.42 and 3.35) than intercropping with poplar (2.78 and 2.76) during both the years. The number of primary branches was significantly influenced by time of planting and varieties. Cucurbits planted in mid-January showed the highest number of primary branches (3.5), at par with mid-December planted crops (3.28) and least in mid-February (2.43). The number of primary branches varied with different cucurbit varieties. PPH-1 hybrid being trailing in nature recorded 3.86 number of primary branches followed by bushy type varieties, PCK-1 (2.86) and PAU-Magaz Kadoo-1 (2.62).
- Days to 50 % flowering was found significant for environment, planting times and varieties during both the years. The variation in environments showed that it took maximum number of days to 50 % flowering under poplar (54.59 and 55.37) than open conditions (52.55 and 55.37). Among the planting times, mid-December planted crop took the maximum number of days to 50 % flowering (57.27 and 56.61) followed by mid- January (52.16 and 52.5) whereas mid-February planted crop took the minimum number of days (51.27 and 51.38) to 50 % flowering. Among varieties, PCK-1 is characterized by early flowering and high ratio of pistillate to staminate flowers, so it took minimum number of days to 50% flowering (47.88 and 47.44) and followed by PPH-1 hybrid (54.27 and 54.33). The maximum no. of days to 50 % flowering was taken by hull-less variety PAU-Magaz kadoo-1 (58.55 and 58.72) during both years.
- During both the experimental years, cucurbit crop intercropped with poplar took more number of days to harvesting (89.63 and 90.25) as compared to sole crop (86.51 and 86.85). Significant differences were recorded among times of planting with maximum number of days to harvesting in early planted crops (92.22 and 92.27) than late planted crops (84.89 and 85.56) during both the years. PCK-1 (80.27 and 80.66) and PPH-1 (90.22 and 91.66) had minimum number of days to harvesting while, PAU-Magaz kadoo-1 took maximum number of days to harvesting (93.72 and 93.83).
- Fruit shape index was found non-significant for environment and planting times but significant for varieties for both the years. PCK-1 being disc-shaped recorded fruit shape index of 0.85 and 0.76. FSI of remaining two varieties, PPH-1 (0.98 and 0.89), PAU-Magaz kadoo-1 (0.99 and 0.94) were recorded during the two experimental years.

- The fruit yield was significantly influenced by growing environments, time of planting and varieties during both the years. The fruit yield per plot was comparatively higher during the year 2019-20 (27.59 and 21.21 kg) than the next successive year (27.02 and 20.44 kg) under open and poplar, respectively. The mid-January (26.24, 25.73 kg) planted crop gave significantly higher fruit yield per plot than the mid-December (24.07, 23.05 kg) and mid-February (22.84, 22.41 kg) planted crop. All three varieties showed good yield per plot based upon their fruit size and growth habit. PPH-1 hybrid, having heavier fruit weight recorded highest fruit yield (32.59, 31.76 kg) per plot followed by PAU-Magaz kadoo-1 (26.64, 25.9 kg) and PCK-1 (13.92, 13.52 kg) during the two experimental years. However, more number of female flowers per plant in PCK-1 gave highest number of fruits per harvest than the other two varieties.
- The fruit yield per hectare was comparatively higher during the year 2019-20 (36.7, 28.2 t/ha) than the successive year, 2020-21 (36.02, 27.24 t/ha) under open and poplar. During both years, mid-January planted crop had highest fruit yield (34.98, 34.3 t/ha) than other planting times. The percentage reduction in fruit yield under five year old canopy recorded was 21.97 % while, under six year old canopy it increased to 24.37 %. Among varieties, minimum reduction in fruit yield under 5 and 6 year old poplar canopy was recorded in variety PCK-1 (19.3 % and 20.56 %).
- Seed yield (q/ha) followed the different trend of fruit yield w.r.t varieties. Highest seed yield was recorded in hulless seeded variety, PAU-Magaz kadoo-1(6.17, 6.07 q/ha) followed by PPH-1(5.04, 4.94 q/ha) and PCK-1 (4.82, 4.71 q/ha). The percentage reduction in seed yield under five year old canopy recorded was 29.6 % while, under six year old canopy it increased to 31.7 %. The minimum reduction in seed yield was recorded in variety PMK-1 (21.8 % and 23.0 %) under 5 and 6 year old poplar canopy, respectively.

Conclusions

- *Cucurbita* spp. can be grown under poplar plantation of five and six year.
- Among planting times, mid-January planted crop showed least percentage reduction (19.0 and 20.0) in fruit yield during both years as compared to and mid-December mid-February planted crop.
- Highest fruit yield was recorded in PPH-1 (43.45, 42.34 t/ha) during first and second year.
- PCK-1 recorded a fruit yield of 18.57 and 18.07 t/ha during the first and second year, respectively. However, it gave more number of fruits per harvest than the other two varieties.

- Hulless seeded variety, PAU Magaz Kadoo-1 recorded highest seed yield of 6.17 and 6.07 q/ha during both the years of study.
- Fruit yield reduction of 21.97 % and 24.37 % was recorded under poplar as compared to open during 2019-20 and 2020-21, respectively. However, it can be compensated by the sale of timber at end of rotation of poplar plantation.
- PPH-1 hybrid gave fruit yield reduction of 23.7 % and 24.63 % during first and second year, respectively.
- PCK-1 recorded minimum percentage reduction in fruit yield, that is, 19.3 % and 20.56 % during first and second year, respectively.
- Growing of hulless variety, PAU-Magaz kadoo-1 under poplar showed minimum seed yield reduction of 21.8% and 23.0% than open during 5 and 6 year age of poplar plantation, respectively.

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APPENDIX I

Mean monthly meteorological data recorded under poplar and open during 2019-20 and 2020-21

	Maximum temperature (^oC)		Minimum temperature (^oC)		Relative humidity (%)	
	Open	**Poplar**	**Open**	**Poplar**	**Open**	**Poplar**
2019-20						
December	15.8	14.6	7.5	6.4	79	82.0
January	16.6	15.4	6.7	5.5	78	83.0
February	21.5	20.5	8.5	7.2	71	77.5
March	24.5	23.7	12.9	11.5	71	75.5
April	32.8	31.2	17.7	16.5	53	58.5
May	36.9	34.6	22.3	21.4	43	49.5
2020-21						
December	19.4	14.2	7.1	6.2	72	80.0
January	16.9	16.1	7.1	5.9	79	84.6
February	23.8	22.9	10.2	8.1	73	82.7
March	29.5	28.4	14.9	12.3	59	76.5
April	34.2	33.7	16.9	16.2	39	60.4
May	36.3	35.1	22.6	21.8	45	51.3

Treatments	PAR				Leaf area index	
	Poplar (5 yr)	**Open**	**Poplar (6 yr)**	**Open**	**Poplar (5 yr)**	**Poplar (6 yr)**
End Dec.	350.9	403.7	363.6	417.2	0.21	0.24
Mid Jan.	309.0	378.8	299.0	372.5	0.17	0.19
End Jan.	450.0	587.3	432.7	572.6	0.14	0.15
Mid Feb.	629.0	701.7	614.1	705.8	0.16	0.18
End Feb.	655.5	754.1	660.7	767.5	0.2	0.21
Mid-March	835.0	977.0	839.0	994.5	0.53	0.55
End March	881.0	1092.0	869.1	1001.2	0.69	0.7
Mid April	993.1	1390.8	970.8	1379.0	0.83	0.85
End April	901.2	1409.5	924.2	1390.8	0.92	0.94
Mid May	828.2	1692.4	819.2	1650.6	1.42	1.45

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