

**PRODUCTIVITY OF OILSEED RAPE (*Brassica napus* L.) AND GARDEN PEA (*Pisum sativum* L.)
INTERCROPPING SYSTEM**

Thesis

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

**MASTER OF SCIENCE
in
AGRONOMY
(Minor Subject: Soil Science)**

By

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CERTIFICATE – I

This is to certify that the thesis entitled, “**Productivity of oilseed rape (*Brassica napus* L.) and garden pea (*Pisum sativum* L.) intercropping system**” submitted for the degree of **M.Sc.** in the subject of **Agronomy** (Minor Subject: **Soil Science**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Suman Pawar (L-2016-A-19-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 investigations have been fully acknowledged.

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ABSTRACT

The study entitled “Productivity of oilseed rape (*Brassica napus* L.) and garden pea (*Pisum sativum* L.) intercropping system”, was carried out at Student’s Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during *rabi* 2016-17 and 2017-18. The soil of the experimental field was loamy sand, normal in pH and electrical conductivity, low in available N, medium in available P and K. The experiment was laid out in randomized complete block design with four replications. The treatments consisted of three cultivars of oilseed rape *viz.*, GSC 6, GSC 7 and Hyola PAC 401 intercropped with garden pea (Punjab 89) in 1:1 (Furrow 60 cm), 1:1 (Flat 60 cm), 1:2 (Flat 90 cm) row proportions, sole GSC 6 (Flat 30 cm), sole GSC 7 (Flat 30 cm), sole Hyola PAC 401 (Flat 30 cm), sole garden pea (Ridge 60 cm) and sole garden pea (Flat 30 cm). Seed yield of oilseed rape cultivars *viz.*, GSC 6, GSC 7 and Hyola PAC 401 were not significantly influenced by different intercropping treatments. Flat sown sole pea produced highest green pod yield which was significantly higher than all other treatments. Significantly higher equivalent yield and system productivity of oilseed rape cultivars was recorded in different intercropping systems with garden pea as compared to the sole oilseed rape crop stand. Land equivalent ratio of different intercropping systems was more than one and was highest in furrow sown Hyola PAC 401 + ridge sown garden pea in 1:1 row ratio (1.18). All the oilseed rape based intercropping systems resulted in higher gross returns when compared to their sole crop stand. Intercropping of GSC6 , GSC 7 and Hyola PAC 401 with garden pea in either 1:1 or 1:2 row ratio makes oilseed rape intercropping system more remunerative because of increase in the net returns to the tune of ₹ 4,200 to ₹11,000 ha⁻¹.

Keywords: Oilseed rape, garden pea, intercropping system, equivalent yield, system productivity, gross returns, net returns, planting methods

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CONTENTS

CHAPTER	TOPIC	PAGE NO.
I	INTRODUCTION	1 – 3
II	REVIEW OF LITERATURE	4 – 15
III	MATERIALS AND METHODS	16 – 31
IV	RESULTS AND DISCUSSION	32 – 68
V	SUMMARY	69 – 72
	REFERENCES	73 – 79
	ANNEXURES	i – ii
	VITA	

LIST OF TABLES

Table No.	Title	Page No.
1	Mechanical properties of the experimental field	19
2	Chemical properties of soil of the experimental field	19
3	Cropping history of experimental field	20
4	Fertilizers applied to crops during cropping season	22
5	Irrigation schedule followed during cropping season	23
6	Periodic plant height of oilseed rape as influenced by different intercropping systems	33
7	Periodic dry matter accumulation of oilseed rape as influenced by different intercropping systems	35
8	Periodic leaf area index of oilseed rape as influenced by different intercropping systems	36
9	Periodic photosynthetically active radiation interception by oilseed rape as influenced by different intercropping systems	38
10	Phenological stages of oilseed rape as influenced by different intercropping systems	40
11	Number of primary and secondary branches of oilseed rape as influenced by different intercropping systems	41
12	Yield attributing characters of oilseed rape as influenced by different intercropping systems	43
13	Seed and stover yield of oilseed rape as influenced by different intercropping systems	44
14	Biological yield and harvest index of oilseed rape as influenced by different intercropping systems	47
15	Quality parameters of oilseed rape as influenced by different intercropping systems	49
16	Periodic plant height of garden pea as influenced by different intercropping systems	50
17	Periodic dry matter accumulation by garden pea as influenced by different intercropping systems	51
18	Yield attributes of garden pea as influenced by different intercropping systems	53
19	Green pod yield of garden pea as influenced by different intercropping systems	54
20	Oilseed rape equivalent yield and system productivity as influenced by different intercropping systems	55
21	Gross returns, net returns and Benefit Cost ratio (B: C) of different oilseed rape based intercropping systems	58

Table No.	Title	Page No.
22	Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER) and Aggressivity as influenced by different intercropping systems	61
23	Competition ratio and Monetary Advantage Index (MAI) of oilseed rape based intercropping system	62
24	Nitrogen, phosphorus and potassium status of soil at harvest as influenced by different intercropping systems	64
25	Nitrogen (N) content and uptake in seed and stover of oilseed rape as influenced by intercropping systems	66
26	Phosphorus (P) content and in seeds and stover of oilseed rape as influenced by intercropping systems	67
27	Potassium (K) content and uptake in seed and stover of oilseed rape as influenced by intercropping systems	68

LIST OF FIGURES

Fig. No.	Title	Page No.
1	Weekly mean meteorological data recorded during the crop season (2016-17)	17
2	Weekly mean meteorological data recorded during the crop season (2017-18)	18
3	Layout plan of experimental area	24
4	Oilseed rape seed yield as influenced by different intercropping systems during 2016-17 and 2017-18	45
5	Oilseed rape equivalent yield as influenced by different intercropping systems during 2016-17 and 2017-18	56
6	Net returns of different oilseed rape based intercropping systems during 2016-17 and 2017-18	59

LIST OF PLATES

Plate No.	Title
1	GSC 6 (60cm, Fr) + GP (R) (1:1)
2	GSC 6 (60cm, F) + GP (F) (1:1)
3	GSC 6 (90cm, F) + GP (F) (1:2)
4	Sole GSC 6 (30cm, F)
5	GSC 7 (60cm, Fr) + GP (R) (1:1)
6	GSC 7 (60cm, F) + GP (F) (1:1)
7	GSC 7 (90cm, F) + GP (F) (1:2)
8	Sole GSC 7 (30cm, F)
9	Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)
10	Hyola PAC 401 (60cm, F) + GP (F) (1:1)
11	Hyola PAC 401 (90cm, F) + GP (F) (1:2)
12	Sole Hyola PAC 401 (30cm, F)
13	Sole GP (60cm, R) at 40 DAS
14	Sole GP (30cm, F) 40 DAS
15	Sole GP (60cm, R) at 80 DAS
16	Sole GP (30cm, F) 80 DAS

CHAPTER I

INTRODUCTION

India achieved great strides in production of food grains, the low level of production of oilseeds is a matter of great concern. But, oilseed crops needs special significance because of shortage of edible oils and huge quantities of oils are still being imported to satisfy the consumptive demands of ever growing population. In India, over 65 per cent of the total vegetable oil produced is derived from soybean and rapeseed-mustard (Singh *et al* 2010). In India, oilseed crops are cultivated on an area of 28.52 million hectares with production of 32.88 million tonnes and productivity of 1.25 t ha⁻¹ during 2016-17 (Anonymous 2018). India ranks third in production of rapeseed and mustard after China and Canada in the world. Worldwide rapeseed and mustard is grown over an area of 37.07 million hectares with production of 73.27 million tonnes and productivity of 1.98 t ha⁻¹ during 2016-17 (Anonymous 2018). Rapeseed and mustard stands second in edible oil production after soybean in India and occupy an area of 6.32 million hectare with production of 7.91 million tonnes and productivity of 1.18 t ha⁻¹ during 2016-17 (Anonymous 2018).

Canola (*Brassica napus* L. and *Brassica campestris* L.) is an important oilseed crop of the world and it ranks third among the oilseed crops after soybean and oil palm in vegetable oil production, while fifth in the oilseed protein production (Khayat 2015). It belongs to *Cruciferae* family and is the most cultivated species of this family (Snowdon *et al* 2006). It is bright-yellow flowering member of the family which is mainly cultivated for its oil rich seed. Moreover, canola (*Brassica napus* L.) is an important oilseed crop under assured irrigation conditions among the different *rabi* oilseed crops. It is an amphidiploid between *Brassica campestris* and *Brassica oleraceae* having 40-45 per cent oil content, 35 per cent crude protein, less than 2 per cent erucic acid and less than 30 micromoles of glucosinolates as compared to other rapeseed and mustard, which have more than 50 per cent erucic acid and 100-120 micromoles of glucosinolates per gram of defatted meal. Canola oil is known to promote good health due to its very low saturated fat and high mono unsaturated fatty acid (MUFA). Therefore, consumption of canola oil poses no unusual health issues, so its consumption in food grade forms has been recognized as safe by United States Food and Drug Administration.

The increasing gap between demand and supply of vegetable oils in the country can be bridged only by increasing their production per unit area per unit time as horizontal expansion in the present situation is considerably impossible. One of the possible means of increasing is to increase by vertical expansion including intercropping with other potential crops. Nowadays, rapeseed-mustard called as oilseed *Brassic*as, has been found successfully

intercropped mainly with different crops *viz.*, chickpea, lentil, sugarcane, potato, wheat, etc. under different agro-climatic zones of India (Singh *et al* 2010).

Intercropping is an advanced agro technique and can be broadly defined as a system where two or more distinct crop species are grown in the same field at the same time during a growing season (Naeem *et al* 2013, Ofori and Stern 1987 and Aziz *et al* 2015). Intercropping aids in improving the agronomic output and economic efficiency of a cropping system than the monoculture through effective use of resources (Khan *et al* 2012) and lowers the risk of crop failure, thus enhancing the stability of production system. So, intercropping in present day agriculture can enhance the productivity of small farms by satisfying the diversified demands of the farmers. Moreover, intercropping involving a mixture of non-legume and legume crop could be more beneficial as it might reduce the costs involved in application of farm inputs by lowering pesticide and fertilizer requirements, thereby, increasing the economic returns in cereal-legume or oilseed-legume intercropping systems.

Brassica based intercropping has assumed vital importance, provides significant advantages in terms of crop productivity, land use efficiency and monetary returns making effective use of solar energy and other inputs as compared to sole cropping under diverse agro-ecological situations. Canola as an oilseed crop can be grown in winter unlike most of the other oilseed crops. Thus, it enables no competition with other oilseed crops (Uzun *et al* 2012). The farmers would be able to utilize the available resources as well as applied inputs more efficiently only if the recommended cropping pattern of mustard with cereals like wheat, barley and with legumes like lentil, pea, chickpea is followed for a specific area. Diepenbrock (2000) also reported that plant density in rapeseed governs the yield components and thus the yield of individual plants and a uniform distribution of plants per unit area is a pre-requisite for yield stability. The appropriate and suitable row ratio combinations is location specific because of change in climatic conditions, cultivated varieties and farming practices undertaken by farmers (Singh *et al* 2010).

In India garden pea (*Pisum sativum* L.) is an important annual vegetable crop belonging to family Fabaceae. It is cool season crop cultivated in northern plains of India as winter vegetable and as summer vegetable in hills as it cannot thrive in summer heat of warmer temperate and lowland tropical climates. It is mainly grown for tender green pods which are used as a fresh vegetable and is a rich source of protein, calcium, phosphorus, iron and vitamins. Being nitrogen fixing legume, this crop is useful for improving soil fertility. Also, early maturing cultivars of this crop fits well into crop diversification programmes under various crop rotations (Rana *et al* 2015). Pea can be grown either as flat or on beds. The raised bed planting method in pea improves water use efficiency, facilitates mechanical weed control and reduces lodging (Singh *et al* 2012).

In oilseed rape, the crop growth during vegetative phase remain quite slow, so there is an ample scope for intercropping of any short duration leguminous crop during initial stages. Among various agronomic factors limiting yield, planting pattern is considered to be of great importance. Therefore, increase in yield can be ensured by maintaining appropriate plant population through different planting patterns. Moreover, an intercropping system involving oilseed and legume leads to increased higher total dry weight and total nitrogen content in the intercrop along with grain nitrogen use efficiency (Cadoux *et al* 2015). Under Punjab conditions, the information on intercropping of oilseed rape with pea is lacking. Moreover, the production potential of different oilseed rape cultivars and pea may vary in relation to different planting methods under different intercropping systems. Keeping in view, the present investigation on “Productivity of oilseed rape (*Brassica napus* L.) and garden pea (*Pisum sativum* L.) intercropping system” was undertaken with the following objectives:

- To evaluate the growth and yield of different oilseed rape cultivars intercropped with garden pea.
- To find out the optimum planting method of oilseed rape and garden pea intercropping system for higher productivity and economic viability.

CHAPTER II

REVIEW OF LITERATURE

A brief review of work pertinent to research on “Productivity of oilseed rape (*Brassica napus* L.) and garden pea (*Pisum sativum* L.) intercropping system” is given under the following headings:

- 2.1 Performance of different oilseed rape cultivars in intercropping system
- 2.2 Performance of pea under different methods of planting/intercropping system
- 2.3 Effect of different row proportions in intercropping system
- 2.4 Effect of row proportions on economics in intercropping system

Intercropping is an intensive land use system with an objective to utilize the space between the rows of main/base crop and to get more produce per unit area (Pandey and Singh 2015). The main objective behind intercropping is to get higher yield on a given piece of land by using resources efficiently, which would have been left unutilized by single crop. It may also lead to out yielding of crops in cereal-legume or oilseed-legume intercropping systems, mainly because of weed suppression and less susceptibility to insects and diseases. This can be achieved by cultivar selection, seeding ratios, planting pattern and by understanding the competition between mixture components which affect the growth of species in intercropping system (Caballero *et al* 1995 and Carr *et al* 2004). The overall density and relative proportions of component crops are important in determining the yield and production efficiencies of species in mixture (Willey and Osiru 1972). The yield advantage obtained through intercropping has been reported due to efficient utilization and optimization of available natural growth resources *viz.*, water, light as well as air and space (Singh and Gupta 1994) and similar results were observed by Tilman *et al* (2002), Marer (2007), Gao and Wu (2014) and Nasri *et al* (2014). The intercropping improves the agronomic output and economic efficiency of a cropping system over monoculture through effective use of resources (Khan *et al* 2012). This is also possible because of the fact that different crop mixtures use these resources more efficiently than crops of same type along with providing mutual benefits to one another, e.g. nitrogen fixation by legumes. Thus, raising the productivity through more effective utilization of available resources is possible through intercropping which occurs due to reduction in weed pressure and thus helps to sustain the plant health. Intercropping also results in higher profitability and productivity (Yildirim and Guvence 2005) due to improvement of soil fertility by nitrogen fixation in legume based intercropping systems (Adesogan *et al* 2000). The extent of beneficial effects of intercropping of non-legumes such as cereals or oilseeds with legumes in terms of crop yield, nutrient uptake by crop, quality of the produce and economic returns differ with crop species, climatic conditions and soil types (Malhi 2012).

2.1 Performance of different oilseed rape cultivars in intercropping system

The cultivars of *gobhi sarson* behave differently in intercropping systems because of the diverse growth habits. Singh and Singh (2014) reported that, growing of oats fodder as an intercrop was able to significantly influence the *gobhi sarson* growth at 60, 90 and 120 days after sowing (DAS) and at the harvest. Cultivar GSC 6 recorded the highest plant height and dry matter accumulation at 60 and 90 DAS as compared to GSL 1. Both varieties recorded significantly lower dry matter accumulation and leaf area index (LAI) at 90 cm spacing in the intercropping system as compared to their sole crops. Similarly at 90 DAS highest LAI of 5.29 and 4.98 was recorded by cultivars GSL 1 and GSC 6, respectively. Oats fodder as an intercrop did not significantly affect phenology of both the cultivars of *gobhi sarson* but significantly higher equivalent yields of *gobhi sarson* cultivars was recorded in intercropping as compared to their sole crop. Another experiment was conducted by Kaur *et al* (2017) to find out the performance of canola oilseed rape, Ethiopian mustard and Indian rape in intercropping system at Ludhiana, Punjab. Highest seed yield was given by Indian rape (11.6 q ha⁻¹) in Ethiopian mustard + Indian rape intercropping system (1:2, 22.5 cm), which was 80.5% of its sole crop yield. Seed yield of non-canola oilseed rape when intercropped with Indian rape (1:1, 22.5cm) was 45.7% lower than its sole crop yield (18.5 q ha⁻¹). However, oilseed rape equivalent yield produced by non-canola oilseed rape + Indian rape (1:1, 22.5cm) was 22.9% higher than sole non-canola oilseed rape. Similarly, sole crop of canola oilseed rape (16.3q ha⁻¹) had 91.0, 60.2 and 35.3 % higher seed yield than its yield under intercropping with Indian rape in different row proportions and spacing. Oilseed rape equivalent yield in canola oilseed rape + Indian rape sown in 1:1 and 2:1 row proportions at 22.5cm row spacing was 16.9 and 20.1% higher than sole canola oilseed rape (16.3 q ha⁻¹). Therefore, canola/non-canola oilseed rape based intercropping system resulted in higher net returns over sole crops. Ethiopian mustard sown as sole crop was more remunerative than its intercropping with Indian rape.

Another field experiment was conducted by Champiri and Bagheri (2013) in order to study the yield and yield components of canola cultivars (*Brassica napus* L.) viz., Hyola and Sarigol as influenced by plant spacing of 15, 25 and 35 cm. They found that for getting maximum canola yield the row spacing of 15 cm had to be maintained, as canola cultivar Hyola 60 at 15cm row spacing produced highest grain yield of 25.6 q ha⁻¹.

Khan *et al* (2012) studied the economic feasibility of different wheat-canola intercropping systems by growing synthetic and hybrid canola genotypes as intercrops. Wheat and canola intercropping with wheat + hybrid canola (4:2) row ratio was found to be more

productive and economically profitable than all other inter and sole crops. Das *et al* (1992) at Jorhat studied the feasibility of intercropping wheat with rapeseed and mustard in different row proportions (1:1, 2:1, 3:1 and 4:1). Sole treatments of wheat, rapeseed and mustard recorded higher yield over paired planting in different row proportions. The yield of Sonalika wheat was better in association with M 27 rapeseed due to its less plant height and short duration. Wheat yield increased with increase in its row proportions in intercropping treatment. Sonalika + M 27 in 1:1 row proportions recorded highest yield, B: C and monetary returns followed by Sonalika+ Pusa Bold in same row proportion due to less seed requirement of wheat and highest net return. The highest LER was recorded in Sonalika + M 27 in 1:1 row proportion, followed by 2:1 row proportion of same combination, which was at par with 4:1 row proportion of Sonalika and Varuna.

An experiment consisting of three varieties of *kabuli* chickpea (BG 1003, L 550 and PBG 2) and two varieties of Indian mustard (Varuna and Vardan) was conducted by Kumar *et al* (2006) to enhance the productivity and profitability of chickpea (*Cicer arietinum*) + Indian mustard (*Brassica juncea*) intercropping system. They reported significantly highest chickpea equivalent yield (17.65 q ha⁻¹) in BG 1003 + Vardan than other intercropping systems. Indian mustard variety Varuna recorded higher number of siliquae per plant, seeds per siliqua and 1000-seed weight than Vardan in the sole cropping as well as in intercropping system with *kabuli* chickpea.

Therefore, it can be said that different cultivars of oilseed rape when intercropped with cereals, legumes or oilseeds prove to be more productive and economically beneficial over their monoculture at different row proportions or spacing.

2.2 Performance of pea under different methods of planting/intercropping system

Planting methods play an important role in the placement of seed at proper depth, as it ultimately affects crop stand, crop establishment, effective root development and interception of solar radiation, ultimately affecting the yield. Therefore, selection of suitable planting method can be considered as non-monetary input for crop production. Selection of planting method depends on planting time as well as availability of soil moisture.

A field experiment was conducted by Singh *et al* (2007) to test the efficacy of herbicides under different planting systems of pea cultivar (Matar Ageta-6). The treatments consists of two planting methods i.e. bed planting (60 cm and two rows on each bed) and flat planting with 30 cm row to row spacing in main plot and weed control treatments in sub plots. Bed planting system was best for obtaining maximum seed production (17.7 q ha⁻¹) due to the favorable environment for root development and ultimately helping better crop stand, hence resulted in more productivity. Ram *et al* (2011) studied growth, productivity and water use of

soybean (*Glycine max*) under different sowing methods and seeding rates in Punjab. The highest seed yield and net returns were recorded in raised bed planting, which was 6.7 and 5.3 per cent higher than ridge-furrow and flat sowing methods, respectively. A three year experiment in maize conducted in North-West of China (Mo *et al* 2018) revealed that planting pattern with one row in a ridge and two rows in a furrow optimized canopy structure, enhanced photosynthetic capacity per plant during grain filling, and accumulated higher aboveground dry matter at physiological maturity, leading to a greater grain yield.

Bhargav *et al* (2018) while investigating the performance of chickpea sown on different seed bed configurations in Malwa region of Madhya Pradesh concluded that paired row of crop at 30 cm spacing on one bed with 50 cm furrow width produced higher number of pods per plant, seed and stover yield were also maximum, which were significantly higher than other treatments and this was also economically more viable intercropping system.

Chen *et al* (2004) while studying the row configuration, protein content and the land equivalent ratio (LER) of barley-pea intercropping system at the Western and Central Agricultural Research Centers (WARC and CARC) of Montana State University, observed that biomass production of barley increased by 41 per cent at WARC and CARC, whereas biomass production of pea decreased 34 per cent at WARC and 46 per cent at CARC with the row configuration changing from the 4:4 to the mixed configuration. The LER ranged from 1.05 to 1.24 on a biomass basis and from 1.05 to 1.26 on a protein basis, indicating the production advantage of intercropping. Furthermore, barley was more competitive crop than pea. The effect on intercrop yield and net returns of pea+ maize on raised bed was also studied by Singh *et al* (2012) in winter season at Jamui. The results revealed that on raised beds maximum equivalent yield was obtained (84.2 q ha⁻¹) where sole crop yields of pea and maize were 48.7 q ha⁻¹ and 43.8 q ha⁻¹, respectively. Another experiment conducted by Singh *et al* (2017) at Kanpur evaluated the suitable intercropping method of mustard, linseed and chickpea with wheat on raised and flat bed system under inner wheel pattern. The intercropping of wheat + chickpea in (1:1) ratio under inner wheel pattern on raised and flat bed systems were found significantly superior over all treatments with respect to LER, gross returns, net returns and B:C in present study.

In brief, it can be concluded that planting pea under bed/ ridge method is more beneficial. Legume based intercropping systems involving raised bed planting were found to be more productive and profitable as compared to flat plating method. Inclusion of pea in intercropping systems involving different crops like *gobhi sarson*, maize and barley results in higher productivity of the system due to higher equivalent yield.

2.3 Effect of different row proportions in intercropping system

In intercropping, arrangement of crops in different row proportions leads to maximum light exposure, prevents excessive humidity, facilitates inter cultivation and leads to efficient use of land and other resources for higher output in terms of yields of component crops.

To determine the feasibility of wheat-canola intercropping systems under two spatial patterns (row and mixed intercropping), Naeem *et al* (2013) observed that, intercropping system consisting of four alternating rows of wheat and canola gave higher LER of 1.37, net benefits of ₹10,7492 and B:C of 2.76. Ali *et al* (2000) also studied the feasibility of canola based wheat intercropping system at Faisalabad and concluded that canola + wheat (1:1) row pattern produced the highest canola seed yield (12.17 q ha⁻¹). Sarkar *et al* (2011) recorded more number of siliquae per plant, seeds per siliqua, seed yield (12.6 q ha⁻¹) and stover yield (28.2 q ha⁻¹) of sole crop of rapeseed (*Brassica campestris*) as compared to its intercropping with baby corn. Singh *et al* (1995) at West Chaparan also studied spatial arrangement in wheat and Indian mustard intercropping and found that wheat and mustard recorded highest yields in their pure stand. Among different row combinations, 3:1 row ratio recorded significantly highest yield of mustard. But highest LER, mean equivalent yield and yield advantage was recorded in 9:1 and 6:2 row ratios. Khan *et al* (2009) conducted an experiment to determine the economic viability of wheat-canola intercropping system during 2006-07. The results revealed that growing of wheat and rapeseed in 3:2 row proportions was proved superior over sole planting of crops. As compared to the sole crop yields of wheat (3.08 q ha⁻¹) and rapeseed seed (2.61 q ha⁻¹), the treatment consisting of wheat and rapeseed in 3:2 row proportions resulted in higher yield (4.65 q ha⁻¹) of wheat. Gangasaran and Giri (1985) at New Delhi recorded that barley + Indian mustard in 4:1, 5:1 or 8:1 row proportions were more remunerative than their sole crops.

Shoaib *et al* (2014) assessed the improvement in forage yield and quality of winter non-legume mixtures. Oats was intercropped with barley and canola under seeding ratios of 3:1, 1:1 and 1:3 for oat: barley and oats: canola along with sole crops. Sole oats produced maximum dry matter yield during both the years. Oats: barley at 3:1 and oats: canola at 1:1 seeding ratio were similar to sole oats. For higher dry matter yield of good quality oats and canola must be seeded at 1:1 ratio.

Aslani and Saeedipour (2015) evaluated the competitive effects of different densities (2:6, 4:4, 6:2, 8:0 and 0:8 plants per pot) of wild mustard as against rapeseed. Maximum height, dry weight, number of branches, number of siliquae per plant, and number of grains per siliqua in wild mustard against the same traits in rapeseed were obtained in their sole treatments. Both the species were equally competitive in exploiting the resources.

Competition coefficient of rapeseed as against wild mustard was greater in 6:2 row ratio treatment. Competition indices revealed that rapeseed was less benefited from more competitive ability than wild mustard.

A study was conducted by Zabih and Saeedipour (2015) in order to evaluate the competitive effects of different densities of rapeseed and broad bean intercropping on weeds growth and rapeseed yield by using replacement series. Planting of broad bean and rapeseed was done as sole crops and also in the different row proportions like 3:1, 2:2 and 1:3 with 20 bushes m⁻². Increase in seed yield, number of siliquae per plant, number of seeds per siliqua and thousand seed weight was due to increase in the plant population of rapeseed. Broad bean was noticed to have higher competitive ability over rapeseed. Significant negative correlation was recorded between rapeseed yield components and broad bean density. Therefore, it can be concluded that higher density of about 25 % of broad bean can cause severe rapeseed yield reduction.

Another study was conducted by Pandey and Singh (2015) to evaluate the effect of intercropping systems and different levels of nutrients on dry matter accumulation and physiological growth parameters of bed planted wheat (*Triticum aestivum* L.). Among the different intercropping systems, canola was found to be more aggressive and competitive to wheat than other component crops and significantly lowered the dry matter accumulation, Kaushik *et al* (2016) conducted an experiment on wheat based intercropping under different row proportions involving chickpea, linseed and mustard in 2:2, 4:2 and 6:2 row proportions. Intercropping of wheat with chickpea proved to be superior in terms of wheat equivalent yield and economics. Similarly, Singh *et al* (2014) advocated the usefulness of mustard + lentil (2:5) owing to highest yield attributes compared to mustard + wheat (1:9) and mustard + lentil (1:5). With 2:4 row ratios of mustard + lentil ,maximum seed yield and stover yield of mustard was recorded which was significant over other row ratios of mustard + wheat (1:6, 1:9, 2:9) and was statistically at par with mustard + lentil (1:5) and mustard + wheat (2:6) row ratios. Mustard equivalent yield (31.28 q ha⁻¹) under intercropping of mustard with wheat in 1:9 row ratio was significantly higher than sole cropping of mustard, wheat and lentil and other remaining intercropping systems. Intercropping of mustard with wheat in 1:9 row ratio showed the highest land equivalent ratio (1.51), aggressivity index (+0.15), net return (₹ 60,468 ha⁻¹) and B:C (4.3). Another field study on competitive indices of wheat + compact mustard intercropping in 5:1 row proportion as influenced by fertilizer doses and seed rates of wheat varieties was conducted by Singh and Bohra (2012). When wheat variety HD-2824 at 1.15 q ha⁻¹ seed rate and 140 % recommended dose of fertilizer was intercropped with compact-mustard variety Sanjukta Aschesh at 100 % recommended dose of fertilizer in 5:1 row proportion, it resulted in best land utilization, maximum productivity and maximum

monetary advantage. In this study monetary advantage index (MAI) based on LER proved to be a better index than intercropping advantage (IA), which is based on actual yield loss (AYL).

Devi *et al* (2014) studied the compatibility of crops such as lentil and mustard in an intercropping system under different spatial arrangements. The study revealed that lentil + mustard under 6:1 and 6:2 intercropping system were found to be more economical and resulted in highest monetary advantage index. Singh *et al* (2000) assessed the suitable plant density and row arrangement of lentil (*Lens culinaris* L.) + mustard (*Brassica juncea* L.) intercropping for higher productivity and consisted of 9 combinations of lentil+ mustard intercropping along with their respective sole cropping. Six intercrop systems were in additive series with 100 % lentil + 25 % and 50 % mustard each in 3 row ratios (2:1, 3:1 and 5:1) and the remaining 3 in replacement series were 33, 25 and 17 % lentil was replaced by mustard in the corresponding row ratios of 2:1, 3:1 and 5:1. Intercropping of 100% lentil+ 25% mustard in 5:1 row ratio produced higher intercrop lentil yield (11.20q ha⁻¹) with additional yield of mustard (7 q ha⁻¹). Singh *et al* (2009) studied the productivity, economics and competitive indices of lentil (*Lens culinaris*) based intercropping systems in Kashmir valley and reported that siliqua length, number of seeds per siliqua and 1000-seed weight of Indian mustard remained unaffected due to various intercrop row ratios with lentil, but irrespective of row ratio, brown sarson produced significantly higher number of siliquae per plant in all row ratios of brown sarson + lentil intercropping compared to its sole crop. In another study, intercropping of lentil with brown sarson reduced the number of siliquae per plant, grains per siliqua and 1,000-grain weight of brown sarson compared to its sole crop (Singh *et al* 2008).

An experiment was conducted in eastern Uttar Pradesh to study the production potential and competitive indices of Indian mustard (*Brassica juncea*) based intercropping with wheat (*Triticum aestivum*) and lentil (*Lens culinaris*) under different row ratios and it was observed that seed yield and stover yield of Indian mustard recorded with Indian mustard + lentil (2:4) was significantly higher over other row ratios of Indian mustard + wheat (1:6, 1:9, 2:9) but was at par with Indian mustard + lentil (1:5) and Indian mustard + wheat (2:6). Intercropping of Indian mustard with lentil in paired rows (30/90 cm) resulted in higher seed yields of component crops, Indian mustard equivalent yield and harvest index (Singh *et al* 2014).

Awal *et al* (2007) while studying the compatibility analysis of mustard and soybean stands in intercrop association, reported reduction of about 17 and 11 per cent in seed yield of Indian mustard in Indian mustard + soybean intercropping system in 1:1 and 2:2 row proportion, respectively as compared to its seed yield under sole cropping (19.8 q ha⁻¹).

Performance of Indian mustard as well as soybean was better in double row intercropping than that in single row intercropping with soybean. They further recorded that seed yield of soybean decreased in Indian mustard + soybean intercropping system in 1:1 (14%) and 2:2 (8%) row ratio compared to its sole crop yield (18.5 q ha^{-1}). Mankotia *et al* (1994) conducted an experiment in which *gobhi sarson* (*Brassica campestris* var. *sarson*) was sole-cropped or intercropped with peas, with *sarson* spaced at 45 or 60 cm or both crops broadcasted, under different rates of N, P and K fertilizer. Growth of *gobhi sarson* was not affected by intercropping with pea nor by row spacing. Intercropping of *gobhi sarson* and peas in rows or broadcast gave higher yields than sole crop of *gobhi sarson*. Intercropping of pea in 1:1 ratio with 45 cm row spacing of *gobhi sarson* produced significantly higher yields of *gobhi sarson* (17.2 q ha^{-1}) and pea (8.9 q ha^{-1}) and *gobhi sarson* equivalent yield (24.2 q ha^{-1}).

An experiment on intercropping of mustard (*Brassica juncea*) with chickpea (*Cicer arietinum*) under different planting systems on eroded soils was conducted by Sachan and Uttam (1992) at Kanpur. They recorded sole treatment of both the crops giving higher yields than their intercropping treatments. The 2:2 row ratio in case of mustard at 45 cm apart and 3:1 ratio in case of chickpea recorded significantly higher grain yield due to higher values of the yield attributes of mustard and chickpea and significantly higher net income ($\text{₹ } 3,368 \text{ ha}^{-1}$) was recorded in chickpea + mustard in 2:2 ratio. Mandal *et al* (1997) recorded highest number of branches per plant (13.84), siliquae per plant (134.46) and seeds per siliqua (13.19) of Indian mustard in intercropping of Indian mustard with lentil or chickpea in 1:1 row ratio than other row ratios.

In another study consisting of oilseed rape and Ethiopian mustard intercropped with *Phaseolus vulgaris* resulted in improvement in various yield attributes (branches per plant, siliquae per plant and seed yield per plant) of oilseed rape and Ethiopian mustard as compared to their respective sole crops, with maximum improvement in 3:1 row arrangement (Khola 1988).

In brief, from the above studies it can be concluded that for higher crop productivity and economic returns, intercropping of oilseed rape should be undertaken rather than its sole cropping. Intercropping of oilseed rape with cereals, pulses and oilseeds in different proportions increase system productivity due to its beneficial effect on various growth and yield components.

2.4 Effect of row proportions on economics in intercropping system

Chaudhary and Singh (1993) at Kangra studied the effect of intercropping *gobi sarson* (Bhawani) and *toria* (HPN 1) and recorded that *gobi sarson* and *toria* in alternate rows

at 22.5 cm spacing was very remunerative and gave higher productivity. From another study conducted by Khola (1988) it was recorded that sole crop of Indian mustard gave higher net returns (₹ 6,827 ha⁻¹) than the intercropping of toria or *P. vulgaris* with Indian mustard, oilseed rape and Ethiopian mustard in different row proportions.

In another experiment conducted by Rana (2006) to evaluate the effect of planting patterns and weed management on weed suppression, productivity and economics of African mustard (*Brassica carinata*) and Indian mustard (*Brassica juncea*) intercropping revealed that paired row planting at 45/105 cm in 2:2 row ratio recorded higher yield (28.2 q ha⁻¹), LER (1.81), net returns (₹ 21,220 ha⁻¹) and B:C (3.84), which were 14.3, 18, 17.7 and 11.8% higher than sole African mustard. Kaur *et al* (2017) recorded higher equivalent yield (22.7 q ha⁻¹), LER (1.41) and net returns (₹ 49,100 ha⁻¹) from oilseed rape + Indian rape at 22.5 cm (2:1).

A study was conducted by Khan *et al* (2009) to determine the economic viability of wheat-canola intercropping system. The results revealed that wheat and rapeseed in 3:2 row proportions resulted in higher yield (4.65 q ha⁻¹) along with higher economic returns of about ₹ 34942 as compared to their sole crops, in which substantial increase in economic returns of ₹11,786 ha⁻¹ (51 per cent) and ₹ 15,302 ha⁻¹ (78 per cent) in wheat and rapeseed respectively was noticed. Ali *et al* (2000) recorded higher net income (₹ 22,487), B: C (2.46) and LER (1.17) from wheat + canola in 1:1 row ratio. Srivastava and Bohra (2006) at Varanasi observed that, association of wheat with Indian mustard under 5:1 row ratio was found to be more sustainable due to higher value of LER and relative crowding coefficient (1.69) and it was economically more remunerative. Indian mustard var. Sanjuncta Aseesh proved economically viable for association with wheat as it results in minimum depression in yield and yield attributes of wheat. Therefore, to achieve higher yield advantage and efficient resource utilization, an application of 100 per cent recommended dose of fertilizer to both the component crops was found to be imperative.

Another field experiment conducted by Singh *et al* (2007) at Faridkot showed that sole sugarcane recorded the highest cane yield (712 q ha⁻¹). The intercropping of gram, peas, wheat, barley, *gobhi sarson* and raya reduced the cane yield by 3.5, 7.6, 9.5, 15.3, 15.3 and 21.3 per cent respectively, as compared to sole cane crop. All the intercropping systems recorded higher cane equivalent yield over sole cane crop except sugarcane + barley. Sugarcane + gram recorded the highest cane equivalent yield (917 q ha⁻¹) and it turned out to be the most profitable intercropping system with the highest net returns (₹ 47,100 ha⁻¹) and the highest B: C (1: 06). Sugarcane + peas was the next profitable intercropping system that gave net returns of ₹ 42,900 ha⁻¹.

Banik *et al* (2000) evaluated the mustard and legume intercropping system under 1:1 and 2:1 system of row replacement series. Under intercropping system, the yield of component crops reduced as against their pure stands. Indian mustard + pea in 1:1 and 2:1 row replacement series and Indian mustard + lentil in 1:1 row replacement series intercropping system resulted in higher net returns (₹ 3,187 ha⁻¹, ₹ 3,325 ha⁻¹ and ₹ 3,235 ha⁻¹, respectively) than sole crop of mustard and lentil (₹ 2,235 ha⁻¹ and ₹ 3,225 ha⁻¹, respectively). But when actual sown proportion was considered, mustard+ lentil (1:1) resulted in maximum intercrop advantage (IA) (+2.889) and actual yield loss (AYL) (+0.438) values. Thus, they concluded that IA and AYL were more appropriate especially, when per plant yield was considered. Shah *et al* (1991) reported higher Indian mustard equivalent yield (22.5 q ha⁻¹) and LER (1.18) from 2:10 row ratio of Indian mustard and pea intercropping system as compared to 1:1, 2:4 and 2:6 row ratios. Significantly higher Indian mustard equivalent yield (23.5 q ha⁻¹) in intercropping system comprising of paired rows (30/90 cm) of Indian mustard + lentil (2 rows) as compared to sole Indian mustard (20.9 q ha⁻¹) was recorded by Singh *et al* (2009). Mandal *et al* (1996) also recorded higher yellow sarson equivalent yield (18.1 q ha⁻¹) in yellow sarson + chickpea (1:2) than other intercropping systems (1:1, 2:1 row ratios).

Singh *et al* (2000) assessed the suitable plant density and row arrangement of lentil (*Lens culinaris* L.) + mustard (*Brassica juncea* L.) intercropping for higher productivity. They observed that intercropping of 100% lentil + 25% mustard in 5:1 row ratio produced as high intercrop lentil yield (11.20 q ha⁻¹) as sole lentil (11.25 q ha⁻¹) with a bonus yield of mustard (7 q ha⁻¹) and maximum lentil equivalent yield (18.50 q ha⁻¹), net return (₹ 19,824 ha⁻¹), LER (1.54), monetary advantage (₹ 8,738 ha⁻¹) and B:C (3.89). Singh *et al* (2008) reported that, in case of intercropping of lentil either with brown sarson or oats in 1:1, 2:1, 4:1 and 6:1 row ratios, lentil with brown sarson in 4:1 row proportion or oats in 2:1 row proportion was most remunerative in respect of net returns (₹ 20,755 ha⁻¹ and ₹ 21,782 ha⁻¹), B: C (3.13 and 2.67) and monetary advantage (₹ 8,370 ha⁻¹ and ₹ 7,760 ha⁻¹, respectively).

A field experiment was conducted by Saran *et al* (1994) to study the production potential of potato and Indian mustard in 5 cropping systems (pure potato, pure Indian mustard and their intercropping in 2:1, 3:1 and 4:1 row proportions at row spacing of 50 cm). The average yield recovery, LER and net returns were significantly higher in potato and Indian mustard in 3:1 intercropping system. Rathi *et al* (1993) also obtained higher net profit (₹ 12,695 ha⁻¹) from Indian mustard and potato intercropping in 1:3 row proportion in comparison to sole border-ridge sown potato (₹ 2,912 ha⁻¹).

Prabhakar and Chandranath (2017) reported that, significantly higher grain yield (44.6 q ha⁻¹), stover yield (64.81 q ha⁻¹), cob length (19.5 cm) and cob weight (251.83 g) was

noticed in intercropping of maize with field pea. When maize was sown between field pea rows three weeks after sowing of field pea, pod yield (15.9 q ha^{-1}), number of pods per plant (20.1), number of seeds per pod (9.7) of pea were higher as compared to all other treatments. When maize was sown between field pea rows two weeks after sowing of field pea, higher B:C (2.36), net returns ($\text{₹ } 47,636 \text{ ha}^{-1}$), LER (1.23) and maize equivalent yield (58.96 q ha^{-1}) were recorded. Nielsen and Jensen (2001) evaluated pea and barley cultivars for complementarities in intercropping at different levels of soil nitrogen availability, in order to determine cultivar complementarities in the intercrop for grain yield, dry matter production and nitrogen acquisition. Six pea (*Pisum sativum* L.) and five barley (*Hordeum vulgare* L.) cultivars were used in the experiment, which were sown as sole crops and intercrops and as mixed crops using replacement design (50:50). LER was used to compare the cultivar performance in intercropping relative to sole cropping and it was observed that barley was stronger competitor among the intercrops and as a result its yield and nitrogen uptake were more as compared to pea. Therefore, from the study it can be concluded that for pea fitting in an intercropping systems, these should have determinate growth, medium root system, light absorption capacity and early development of symbiotic association for nitrogen fixation for supporting high growth rate during early stages of growth.

To study influence of different row proportions on yield of *rabi* crops under different intercropping systems an experiment was conducted by Kumar *et al* (2009). They reported that Intercropping chickpea + Indian mustard in 4:2 row ratio resulted in highest gross returns ($\text{₹ } 38,960 \text{ ha}^{-1}$), net returns ($\text{₹ } 29,923 \text{ ha}^{-1}$) and B:C (4.30) than sole crop of chickpea ($\text{₹ } 32,391 \text{ ha}^{-1}$, $\text{₹ } 24,744 \text{ ha}^{-1}$, 4.23) and sole crop of Indian mustard ($\text{₹ } 22,756 \text{ ha}^{-1}$, $\text{₹ } 15,229 \text{ ha}^{-1}$, 3.02). Intercropping of chickpea + Indian mustard in 4:2 row ratio resulted in higher (1.37) land equivalent ratio (LER) followed by 3:1 row ratio (1.15) than sole crops. Indian mustard + chickpea in 1:8 row proportion recorded higher LER followed by 1:6 planting pattern of Indian mustard + chickpea (Gangasaran and Giri 1985). Chickpea + Indian mustard in 6:3 row ratio resulted in highest net profit ($\text{₹ } 31,450 \text{ ha}^{-1}$) and B:C (2.48) compared to other row proportions (Yadav *et al* 2013). Kushwaha (1992) recorded higher LER in case of Indian mustard + chickpea than Indian mustard + lentil intercropping system at Kanpur.

Sahota and Malhi (2012) assessed the agronomic and economic considerations under barley-pea intercropping system and studied the effect of intercropping of barley (non-legume) and pea (legume) on grain yield, grain quality (protein concentration), LER, nitrogen uptake and economic returns. Barley and pea were grown both as mono crops and also as intercrops in combinations (both in the same row and alternate rows). In barley- pea intercropping system, barley yield was higher than sole barley plot by 2.7 q ha^{-1} with alternate

row combination and by 2.23 q ha⁻¹ when both crops were sown in same rows. In sole crop of barley crop, protein concentration in grain increased with application of nitrogen. But when comparison was made with barley as sole crop with zero nitrogen, protein concentration in barley grain was increased when it was intercropped with pea. In barley + pea inter crop treatments, application of nitrogen had non- significant influence on protein concentration in barley grain, but protein concentration in barley grain was less than protein concentration in pea grain. Another experiment was carried to determine the productivity and yield quality of oats and two species of grain legumes (pea – *Pisum sativum* L. and lentil – *Lens culinaris* L.), in intercropping system by Dusa (2013) to understand and evaluate their adaptability under natural conditions. Oats and grain legumes were sown in alternative rows (oat + pea and oat + lentil in 1:1 row ratio), at the spacing of 12.5 cm between the rows. On an average, oat yield intercropped with pea and lentil was 14.0 q ha⁻¹ and 13.5 q ha⁻¹ respectively. In intercropping, the yield of pea was 7.9 q ha⁻¹ and it was less than that in the sole cropping (27.5 q ha⁻¹). Lal *et al* (1998) also reported higher seed yield of pea in its sole crop stand when compared to its seed yield in intercropping systems. The lentil crop intercropped with oat produced yield of 7.7 q ha⁻¹ than sole crop stand of lentil. The highest value of LER (1.50) was recorded in oat + pea intercropping system. In oat + lentil intercropping, LER value was 1.40. The highest protein yield was obtained in sole pea treatment i.e. 7.3 q ha⁻¹. In oat-pea intercropping system (Dusa 2013) highest protein yield (7.0 q ha⁻¹) had been recorded as compared to the oat-lentil intercropping system (3.7 q ha⁻¹).

From the above mentioned studies, it can be concluded that intercropping of *gobhi sarson* gave higher equivalent yield as compared to the sole crop. Inclusion of component crops in different row proportions results in achieving higher yield advantage and efficient resource utilization in terms of higher equivalent yields and LER. Bed/ ridge sowing of peas resulted in higher yield due to better utilization of available resources. Intercropping system involving legumes improve nitrogen uptake and protein content of main crop along with improving economic returns.

CHAPTER III

MATERIAL AND METHODS

The present study entitled “Productivity of oilseed rape (*Brassica napus* L.) and garden pea (*Pisum sativum* L.) intercropping system” was conducted at Students’ Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during *rabi* seasons of 2016-17 and 2017-18.

3.1 Location and climate

Ludhiana is situated in Trans-Gangetic agro-climatic zone, representing the Indo-Gangetic Alluvial plain at 30° 56' N latitude, 75° 48' E longitude and at an altitude of 247 m above mean sea level. Ludhiana is characterized by sub-tropical semi-arid type of climate with hot summers and very cold winters. The mean maximum and minimum temperature show considerable fluctuation during summer and winter. The maximum temperature above 38°C is common during summer and frequent frosty spells are experienced during winters, especially in December and January. The average annual rainfall is 705 mm, approximately 80 per cent of which is received during July to September.

3.2 Weather during the crop season

The meteorological data for crop season was obtained from the School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana during the crop growing seasons (*rabi* 2016-2017 and 2017-18) and it is presented in appendix-I and depicted in fig.1 and 2. The mean weekly maximum and minimum temperatures during crop season of 2016-17 ranged from 16.4 to 35.4 °C and 3.5 and 18.9 °C, whereas, during the crop season of 2017-18, it ranged from 15.5 to 34.8 °C and 5.3 to 20.3 °C, respectively. The maximum (35.4 °C) and minimum (3.5 °C) temperature were recorded during 13th and 2nd standard meteorological week (SMW) during crop season of 2016-17, whereas, in crop season of 2017-18, maximum (34.8 °C) and minimum of (5.3 °C) temperature were recorded during 14th and 2nd SMW, respectively. The mean weekly relative humidity (RH) ranged from 81.4 to 56.1 per cent and 51 to 77 per cent during the crop season of 2016-17 and 2017-18, respectively.

The total rainfall of 14.5 mm and 30.8 mm during 2016-17 and 2017-18, respectively was recorded. The maximum weekly rainfall of 5.8 and 18 mm was recorded during 4th SMW during 2016-17 and 2017-18, respectively. Maximum and minimum evaporation of 6 mm and 0.9 mm, respectively were recorded during 13th and 49th SMW of cropping season 2016-17, whereas, in cropping season of 2017-18 maximum and minimum evaporation of 42.2 mm and 1.1mm, respectively was recorded during 45th and 14th SMW during cropping season of 2017-18. Weekly sunshine hours ranged from 2.6 to 10.9 hours and 2.0 and 12.4 hours during cropping season 2016-17 and 2017-18, respectively. Consequently more number of irrigations were given to crop during first year than second year.

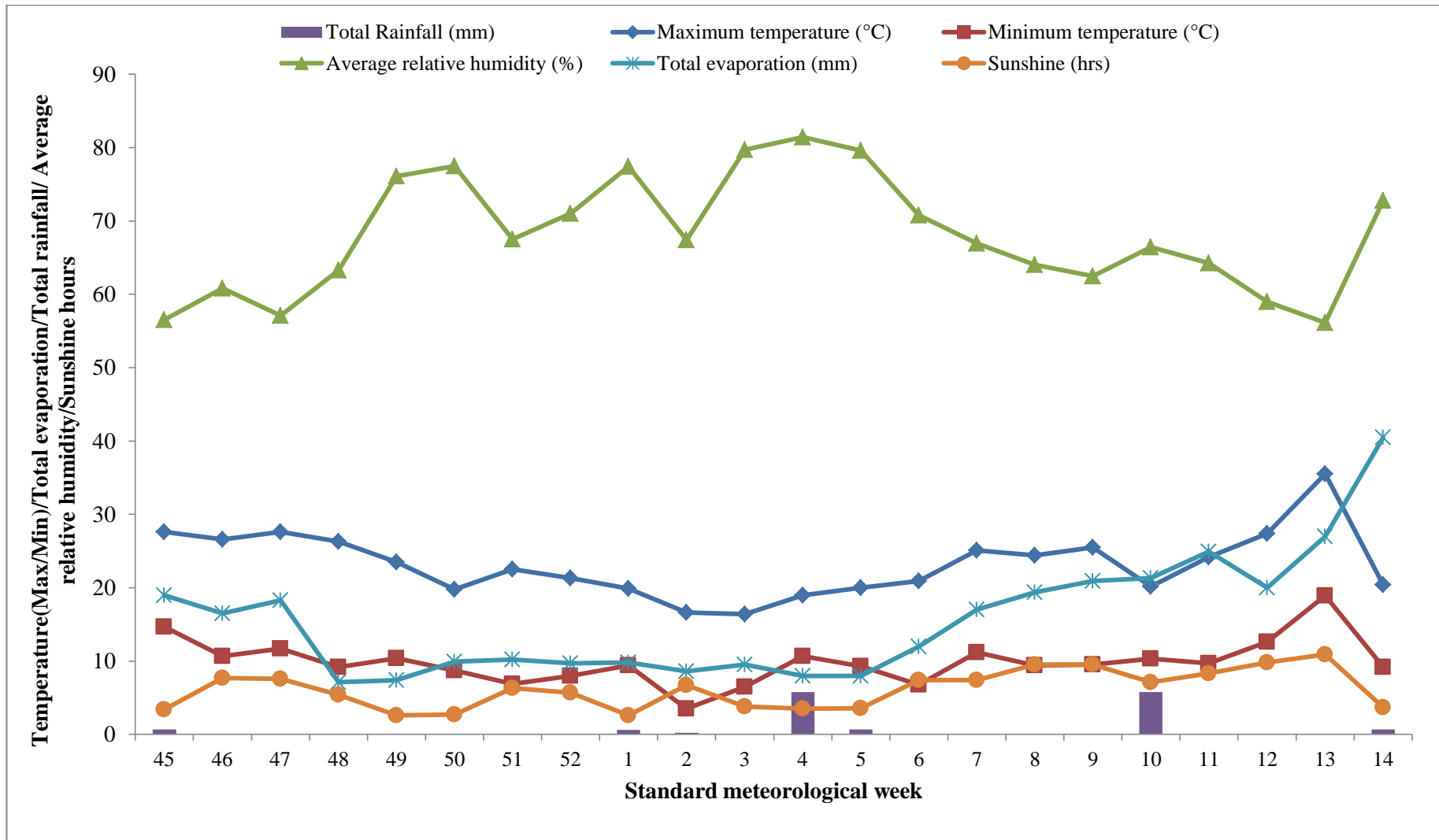


Fig. 1: Weekly mean meteorological data recorded during the crop season (2016-17)

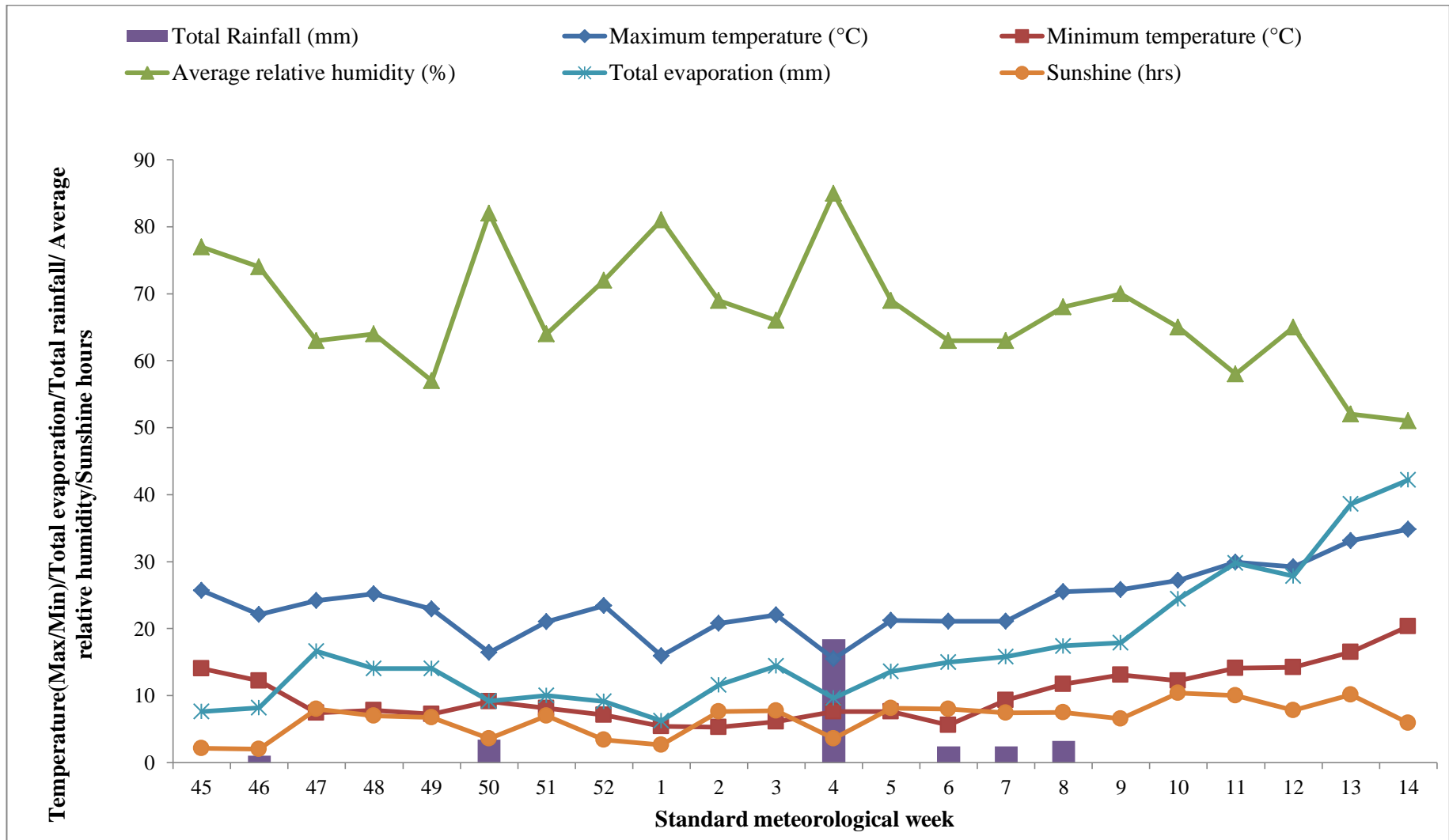


Fig. 2: Weekly mean meteorological data recorded during the crop season (2017-18)

3.3 Soil sampling and analysis

Soil samples were collected from four randomly selected spots at 0-15 and 15-30 cm depth from the experimental field before initiating the experiment and then two composite samples were prepared. These composite samples were air dried and sieved through 2 mm sieve and finally subjected to physical and chemical analysis to determine the soil properties of the experimental site.

3.3.1 Mechanical analysis

The mechanical analysis of soil at 0-15 cm depth was done and the physical properties of the soil are represented in table 1.

Table 1: Mechanical properties of the experimental field

Fraction	Proportion (%)	Method used
Sand	79.5	International Pipette Method (Piper 1966)
Silt	8.2	
Clay	13.1	
Textural class	Loamy sand	

3.3.2 Chemical properties

Chemical analysis of composite soil samples taken from 0-15 cm and 15-30 cm depth revealed that the soil of the experimental field was normal in pH and electrical conductivity, low in organic carbon and available nitrogen, medium in available phosphorus and medium in available potassium.

Table 2: Chemical properties of soil of the experimental field

Parameters	Soil depth (cm)		Rating	Analytical method employed
	0-15	15-30		
pH (1:2, soil: water suspension)	7.2	7.5	Normal	Beckman's glass electrode pH meter in 1:2 soil-water suspension (Jackson 1967)
Electrical conductivity (ds m ⁻¹) at 25 °C	0.20	0.26	Normal	In 1:2 soil-water suspension with solubridge conductivity meter (Jackson 1967)
Organic carbon (%)	0.24	0.18	Low	Walkley and Black's (1934) rapid titration method
Available N (kg ha ⁻¹)	163.1	156.8	Low	Modified alkaline potassium permanganate method (Subbiah and Asija 1956)
Available P (kg ha ⁻¹)	21.6	18.4	Medium	0.5 N sodium bicarbonate extractable P (Olsen <i>et al</i> 1954)
Available K (kg ha ⁻¹)	152.1	195.2	Medium	1 N ammonium acetate extractable K (Merwin and Peech 1950)

3.4 Cropping history of the field

The crops grown in the experimental field during preceding years are as follows (Table 3).

Table 3: Cropping history of experimental field

Year	Crop season	
	<i>Kharif</i>	<i>Rabi</i>
2015-16	Arhar	Wheat
2016-17	Maize	Oilseed rape + garden pea (Experiment)
2017-18	Maize	Oilseed rape + garden pea (Experiment)

3.5 Experimental details

3.5.1 Name of the experiment: “Productivity of oilseed rape (*Brassica napus* L.) and garden pea (*Pisum sativum* L.) intercropping system ”

Location of experiment: Student’s Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana.

Treatments: 14

- T₁: Oilseed rape cultivar GSC 6 (in furrows) + garden pea (on ridges) (1:1)
- T₂: Oilseed rape cultivar GSC 6 (flat sown) + garden pea (flat sown) (1:1)
- T₃: Oilseed rape cultivar GSC 6 (flat sown) + garden pea (flat sown) (1:2)
- T₄: Oilseed rape cultivar GSC 7 (in furrows) + garden pea (on ridges) (1:1)
- T₅: Oilseed rape cultivar GSC 7 (flat sown) + garden pea (flat sown) (1:1)
- T₆: Oilseed rape cultivar GSC 7 (flat sown) + garden pea (flat sown) (1:2)
- T₇: Oilseed rape cultivar Hyola PAC 401 (in furrows) + garden pea (on ridges) (1:1)
- T₈: Oilseed rape cultivar Hyola PAC 401 (flat sown) + garden pea (flat sown) (1:1)
- T₉: Oilseed rape cultivar Hyola PAC 401 (flat sown) + garden pea (flat sown) (1:2)
- T₁₀: Sole oilseed rape cultivar GSC 6 (flat sown)
- T₁₁: Sole oilseed rape cultivar GSC 7 (flat sown)
- T₁₂: Sole oilseed rape cultivar Hyola PAC 401 (flat sown)
- T₁₃: Sole garden pea (on ridges)
- T₁₄: Sole garden pea (flat sown)

Abbreviations used:

T₁: GSC 6 (60cm, Fr) + GP (R) (1:1)

T₂: GSC 6 (60cm, F) + GP (F) (1:1)

T₃: GSC 6 (90cm, F) + GP (F) (1:2)

T₄: GSC 7 (60cm, Fr) + GP (R) (1:1)

T₅: GSC 7 (60cm, F) + GP (F) (1:1)

T₆: GSC 7(90cm, F) + GP (F) (1:2)

T₇: Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)

T₈: Hyola PAC 401 (60cm, F) + GP (F) (1:1)

T₉: Hyola PAC 401 (90cm, F) + GP (F) (1:2)

T₁₀: Sole GSC 6 (30cm, F)

T₁₁: Sole GSC 7 (30cm, F)

T₁₂: Sole Hyola PAC 401 (30cm, F)

T₁₃: Sole GP (60cm, R)

T₁₄: Sole GP (30cm, F)

[Where, Fr- furrow, F- flat, R-ridge and GP- garden pea]

Total number of treatments	:	14
Experimental design	:	Randomized complete block design
Number of replications	:	4
Number of plots	:	56
Gross plot size	:	7m×3m=21 m ²
Variety/Hybrid	:	Oilseed rape (GSC 6, GSC 7 and Hyola PAC 401) Garden pea (Punjab 89)
Year of conduct	:	Rabi 2016-17 and 2017-18

The row to row spacing was 30 cm in sole oilseed rape. The row spacing of oilseed rape was 60 and 90 cm in 1:1 and 1:2 row patterns, respectively. The same plant population of oilseed rape was maintained in the intercropping system as in sole stand. In ridge planting method, the ridges were made at 60 cm row spacing and garden pea was sown on the top of ridges and oilseed rape in furrows. In garden peas, row to row spacing was 30 cm for flat and 60 cm in case of ridge planting.

3.6 Agronomic practices

Agronomic practices followed for raising oilseed rape and garden pea are given below:

3.6.1 Field preparation

A primary tillage operation of experimental field was done with tractor drawn disc harrow before pre sowing irrigation. A heavy pre-sowing irrigation (10cm) was applied to

ensure adequate moisture in the soil profile at the time of planting. Field was cultivated twice with the help of cultivator, followed by planking for ideal seed bed preparation. In the levelled field, plots and irrigation channels were made as per the layout plan (Fig 3) of the experiment.

3.6.2 Seed rate, sowing and spacing

The sowing of oilseed rape (main crop) varieties GSC 6, GSC 7 and Hyola PAC 401 and garden pea (inter crop) variety Punjab 89 was done by *kera* method using recommended seed rates 3.75 kg ha⁻¹ and 112.5 kg ha⁻¹ of main and intercrop (on area basis), respectively, during the *rabi* season of 2016-17 and 2017-18. The seeds of garden pea were inoculated with *Rhizobium leguminosarum* strain. Sowing of both the crops was done on 9th November, 2016 and on 7th November, 2017. The row spacing of oilseed rape was 60 and 90 cm in 1:1 and 1:2 row patterns, respectively. In sole planting, oilseed rape was sown at 30 cm row spacing. Whereas, sole garden pea was sown at 30 cm and 60 cm in flat and on ridges, respectively. The plant population of oilseed rape was kept same in the intercropping system. In case of ridge planting method of garden pea, the ridges were made at 60 cm row spacing and pea was sown on the top of ridges and oilseed rape in furrows.

3.6.3 Fertilizer application

The fertilizers were applied to both oilseed rape and garden pea as per their recommended doses (Table 4). Half of N and full dose of P was applied to oilseed rape at the time of sowing, while the remaining half of N was applied with first irrigation. Full dose of nitrogen and phosphorous were applied to garden pea at the time of sowing on area basis. Nitrogen and phosphorus were applied in the form of urea and single super phosphate, respectively.

Table 4: Fertilizers applied to crops during cropping season

Sr. No.	Crop	Recommended Dose (kg ha ⁻¹)		
		N	P ₂ O ₅	K ₂ O
1	Oilseed rape	150	30	-
2	Garden pea	50	62.5	-

3.6.4 Thinning and gap filling

After establishment of plants, thinning and gap filling of oilseed rape was carried out at 20 DAS to maintain the same plant population in all plots by keeping plant to plant distance of 5 cm, 3.5 cm and 10 cm in 1:1, 1:2 row pattern and in sole crop respectively. In case of garden pea gap filling was done at 12 DAS. The thinning and gap filling operations were done within row in each plot to maintain the proper plant population during both experimental seasons.

3.6.5 Hoeing and weeding

Weeds were kept under check with hand weeding. Two hand hoeings at 30 and 65 DAS were done to keep the experimental field free from weeds during both the seasons.

3.6.6 Irrigation

The irrigation was applied on following dates as mentioned in table 5 for both the field experiments according to the main crop requirement. During the second year third irrigation was skipped because of 18 mm of rainfall received during fourth standard meteorological week.

Table 5: Irrigation schedule followed during cropping season

Irrigation	Days after sowing (DAS)	
	2016-17	2017-18
First	30	30
Second	70	72
Third	110	-

3.6.7 Plant protection measures

Spodic menace of leaf eating caterpillar was observed in oilseed rape at 60 DAS during 2016-17 and at 100 DAS during 2017-18. It was controlled by spraying Ekalux 25 EC (quinalphos) @ 1000 ml ha⁻¹ in 250 litres of water during both the years. Spraying of Malathion 50 EC (malathion) @ 1000 ml ha⁻¹ and Rogor 30 EC (dimethioate) @ 1000 ml ha⁻¹ was done alternatively with 10 days interval to control mustard aphid during both the cropping seasons at the time of flowering.

3.6.8 Harvesting of garden pea

Three pickings of garden pea was done in both intercropped and sole cropped plots i.e. first, second and third picking on 17th Feb, 23rd Feb & 2nd March 2017 and 16th Feb, 22nd Feb & 2nd March 2018, during first and second year, respectively. From each net plot, the pod yield was recorded and converted in to q ha⁻¹.

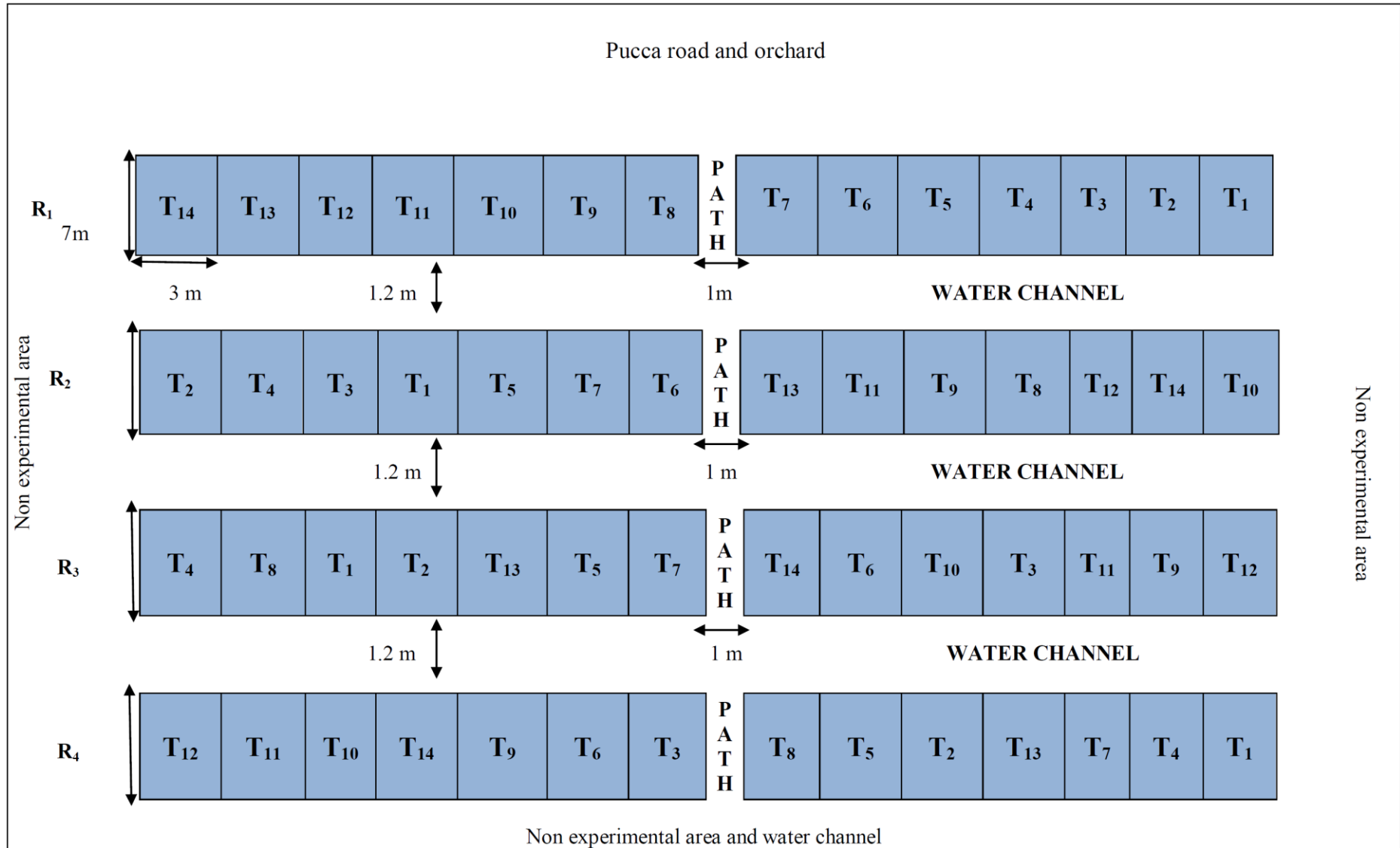


Fig 3: Layout of experimental field

3.6.9 Harvesting and threshing of oilseed rape

The crop (oilseed rape) was harvested manually when it attained the physiological maturity. Harvesting of crop i.e. oilseed rape varieties GSC 6 and GSC 7 was done on 31st March, 2017 and on 3rd April, 2018 and harvesting of Hyola PAC 401 was done on 3rd and 5th April, 2017 and 2018, respectively from net plot area. The harvested crop was tied in to bundles and bundle weight was taken to record the biological yield. The net plot-wise threshing and cleaning operations were done to record seed yield. Net plot size for oilseed rape in 1:1, 1:2 and in sole crop stand was 5m×1.8m (3 rows), 5m×1.8m (2 rows), 5m×1.8m (6 rows), respectively. While net plot size for garden pea intercropped with oilseed in 1:1 and 1:2 and in sole crop stand was 5m×1.8m (3 rows), 5m×0.6m (2 rows), 5m×1.8m (3 rows on ridge and 6 rows in flat), respectively.

3.7 Observations for oilseed rape

3.7.1 Growth parameters

3.7.1.1 Plant height

The plant height was taken periodically at 40, 80, 120 DAS and at harvest of crop. Five plants were selected randomly from each plot and plant height was measured from the base of the plant i.e. ground level to base of fully opened leaf in each plot of all the replications. An average value for each plot was computed and expressed in centimetres.

3.7.1.2 Leaf Area Index (LAI)

The leaf area of component crops was recorded at 40, 80, 120 DAS and at harvest from each plot. Sun scan canopy analyzer was used for recording LAI.

3.7.1.3 Photosynthetically Active Radiation (PAR)

Penetration of PAR in the range of 0.40 to 0.76 microns was measured between 12:00 noon to 2:00 pm with the help of Line Quantum sensor. The incoming and outgoing solar radiation at the top of crop canopy and radiation penetration at the ground surface under the crop canopy was measured. The observations were recorded randomly from two places in each plot. The PAR interception was calculated as follows:

$$\text{PAR (\% Interception)} = \frac{\text{PAR (I)} - \text{PAR (T)} - \text{PAR (R)}}{\text{PAR (I)}} \times 100$$

Where,

PAR (I) = Total PAR incoming above the canopy, Wm^{-2}

PAR (T) = PAR transmitted to ground, Wm^{-2}

PAR (R) = PAR reflected from the canopy, Wm^{-2}

3.7.1.4 Dry Matter Accumulation (DMA)

Dry matter accumulation was recorded at 40, 80, 120 DAS and at harvest. At each sampling plants were taken from 0.5 m row length from each plot. The above ground biomass was first air dried and then oven dried at 60-65°C for 48 hours and was expressed in $q\ ha^{-1}$.

3.7.2 Phenological observations

3.7.2.1 Days taken to 50 per cent emergence

Number of days taken to 50 per cent emergence was recorded from marked length of one meter from two spots. The date when 50 per cent seeds emerged out under each treatment was recorded and the number of days from sowing to this date was counted and referred to as the number of days taken for 50 per cent emergence.

3.7.2.2 Days taken to 50 per cent flowering

This stage was recorded when five plants out of ten selected plants of oilseed rape from three places in each plot had borne one or more flowers. The number of days from sowing to this stage was counted as days taken to 50 per cent flowering.

3.7.2.3 Days taken to 50 per cent siliquae formation

Ten plants from three places of each plot were selected. The days when one or more siliquae appeared on five out of ten selected plants were recorded. The number of days taken to attain this stage was recorded to as the days taken to 50 per cent siliquae formation.

3.7.2.4 Days taken to maturity

The maturity of crop was indicated as the plant stage when stem and branches became pale yellow to violet brown, siliquae turned lemon yellow and seeds became brown to black in colour. The number of days from sowing to this date was counted and referred to as number of days taken for maturity.

3.7.3 Yield attributing characters and yield

3.7.3.1 Branches per plant

The number of primary and secondary branches per plant in each treatment was counted at maturity from five randomly selected plants and computed as mean number of primary and secondary branches per plant.

3.7.3.2 Siliquae per plant

Number of mature siliquae from five randomly selected plants were taken from each plot at the harvest and from this mean number of siliquae per plant was calculated.

3.7.3.3 Seeds per siliqua

Numbers of seeds from five randomly selected siliqua in each plot was recorded at harvest and their average value was expressed as number of seeds per siliqua.

3.7.3.4 1000 seed weight

Seed samples were drawn randomly from the finally threshed, winnowed and cleaned produce of each net plot and thousand seeds from produce of each net plot were counted and weighed.

3.7.3.5 Seed yield

After threshing, winnowing and cleaning, produce of each net plot was weighed separately and was expressed as seed yield in $q\ ha^{-1}$ and adjusted to the moisture level at 8%.

3.7.3.6 Biological yield

The weight of the harvested and thoroughly sun dried above ground produce of each plot was recorded separately before threshing and was expressed in $q\ ha^{-1}$.

3.7.3.7 Harvest Index (HI)

The harvest index was calculated by dividing economic (seed) yield by the total biological (seed + stover) yield and was expressed in percentage.

$$HI (\%) = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.7.4 Quality parameters

3.7.4.1 Protein content in seeds of oilseed rape

Protein content in oilseed rape seeds was calculated by multiplying the nitrogen content in seeds with 6.25 factor and expressed in percentage.

3.7.4.2 Oil content in seeds of oilseed rape

The oil content in seed was determined with MQC benchtop Nuclear Magnetic Resonance (NMR) Analyzer (Oxford instruments, UK) by using non-destructive method of oil estimation as suggested by Alexander *et al* (1967).

3.8 Observations for garden pea

3.8.1 Plant height

The plant height was measured from the base of the plant i.e. ground level up to base of last fully opened leaf of the main shoot of the randomly selected five plants in each plot of all replications at 40, 80 DAS and at harvest of crop and an average value for each plot was computed and expressed in centimetres.

3.8.2 Dry Matter Accumulation (DMA)

DMA was recorded at 40, 80 DAS and at harvest of crop. At each sampling two plants were taken from each plot. The above ground biomass was first air dried and then oven dried at 60-65°C for 48 hours and expressed in $g\ plant^{-1}$.

3.8.3 Seeds per pod

Ten pods were randomly taken from harvested pods of each plot and number of seeds per pod were counted and expressed as average.

3.8.4 100 seed weight

Pod samples from each plot were drawn randomly and their 100 representative seeds were counted and weighed. The weight of 100 seeds was recorded as seed index for each plot.

3.8.5 Green pod yield of garden pea

Fresh pods were harvested from each net plot i.e. from intercrop and sole crop plots. Their fresh weight from all the pickings was recorded in kg plot⁻¹ and it was converted in to q ha⁻¹.

3.9 Competitive indices

3.9.1 Land Equivalent Ratio (LER)

LER indicates the efficiency of intercropping in using the resources of the environment as compared to sole cropping (Mead and Willey 1980). It is a widely used index to assess any yield advantages in intercropping systems and it measures the efficiency of an inter/mixed crop. Moreover, LER indicates the total land area required by sole crops to achieve the same yield as the intercrops (Willey 1985). When the LER is >1, intercropping favors the growth and yield of the species. When LER is <1, intercropping negatively affects the growth and yield of the plants grown in mixtures (Caballero *et al* 1995). LER is according to the following formula:

$$LER = LER_a + LER_b$$

Where:

$$LER_a = Y_{ab}/Y_{aa},$$

LER_a for crop 'a' under intercropping system

Y_{aa} = Pure stand yield of crop 'a'

Y_{ab} = Yield of crop 'a' (when intercropped with crop b)

$$LER_b = Y_{ba}/Y_{bb}$$

LER_b for crop 'b' under intercropping system

Y_{bb} = Pure stand yield of crop 'b'

Y_{ba} = Yield of crop 'b' (when intercropped with crop a).

3.9.2 Area Time Equivalent Ratio (ATER)

ATER provides more realistic comparison of the yield of intercropping over monocropping in terms of time taken by component crops in the intercrop according to Hiebsch and McCollum (1987). ATER is calculated by formula area time equivalent ratio.

$$\text{ATER} = \frac{\{(L_a \times D_a) + (L_b \times D_b)\}}{T}$$

Where, L_a and L_b are the partial LER of component crops 'a' and 'b'; D_a and D_b indicates the duration of component crops and T is the total duration of the intercropping system.

3.9.3 Aggressivity (A)

Aggressivity is another index that is often used to indicate how much the relative yield increase in crop 'a' is greater than that for crop 'b' and vice versa in an intercropping system. This was proposed by McGilchrist (1965) and was determined according to the following formula:

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

$$A_{ba} = \frac{Y_{ba}}{Y_{bb} \times Z_{ba}} - \frac{Y_{ab}}{Y_{aa} \times Z_{ab}}$$

Where:

A_{ab} is the aggressivity of crop 'a' intercropped with 'b'

A_{ba} is the aggressivity of crop 'b' intercropped with 'a'

Z_{ab} is the sown proportion of intercrop 'a' in combination with 'b'

Z_{ba} is the sown proportion of intercrop 'b' in combination with 'a'

3.9.4 Competitive Ratio (CR)

CR was calculated by the following formula as given by Willey and Rao (1980).

$$CR_a = \frac{LER_a}{LER_b} \times \frac{Z_{ba}}{Z_{ab}}$$

$$CR_b = \frac{LER_b}{LER_a} \times \frac{Z_{ab}}{Z_{ba}}$$

Where:

LER_a and LER_b represents partial land equivalent ratio of crop 'a' and 'b' respectively.

CR_a , CR_b are the competitive ratio for 'a' and 'b' intercrops

Z_{ab} is the sown proportion of intercrop 'a' in combination with 'b'

Z_{ba} is the sown proportion of intercrop 'b' in combination with 'a'

3.9.5 Monetary Advantage Index (MAI)

The monetary advantage index (MAI) was calculated as described by Ghosh (2004).

$$\text{MAI} = \text{Commercial value of combined intercrops} \times \frac{\text{LER} - 1}{\text{LER}}$$

The higher the index value, the more profitable is the cropping system (Dhima *et al* 2007).

3.10 Economic analysis

3.10.1 Equivalent yield of oilseed rape

Yield of individual crop was converted into equivalent yield ($q\ ha^{-1}$) on the basis of prevailing market price of the crop (Anjaneyulu *et al* 1982). It was calculated by the following formula:

$$EY = \text{Yield of oilseed rape} + \frac{\text{Yield of garden pea} \times \text{Price of garden pea}}{\text{Price of oilseed rape}}$$

3.10.2 Gross returns

The gross returns in terms of rupees per hectare was worked by multiplying the seed and stover yield of oilseed rape with prevailing market price. The market price of oilseed rape and garden pea were ₹ 3700 & ₹ 830 and ₹ 4000 & ₹ 850 q^{-1} during 2017 and 2018, respectively.

3.10.3 Net returns

Net returns ($₹\ ha^{-1}$) of each treatment was calculated by deducting the total cost of cultivation from the gross returns.

3.10.4 Benefit Cost Ratio (B: C)

The B: C was calculated with the help of following formula:

$$B:C = \frac{\text{Gross returns } (₹\ ha^{-1})}{\text{Total cost of cultivation } (₹\ ha^{-1})}$$

3.11 Plant analysis

3.11.1 Sampling and preparation of oilseed rape samples

The samples of oilseed rape were collected at harvest, dried in sun and then oven dried at 60° C for 48 hours. Then samples were analyzed for total nitrogen, phosphorus and potassium content.

3.11.2 Estimation of nitrogen

The estimation of total nitrogen content was done by digesting the 0.5 g samples with concentrated 10 ml H_2SO_4 and digestion mixture in micro Kjeldhal's assembly as given by Jackson (1967).

3.11.3 Estimation of phosphorus

The phosphorus content of samples was estimated by Vanadomolybdo- phosphoric yellow colour method in HNO_3 as suggested by Jackson (1967). Sample weight of 0.5 g was

digested in triple acid mixture of HNO₃: HClO₄: H₂SO₄ in the ratio of 9:3:1. The intensity of yellow colour was taken at 470 nm wave length using Elico spectrophotometer model CL24.

3.11.4 Estimation of potassium

Potassium concentration in the plant acid extract was estimated by using the flame photometer method. Reading was taken by using Elico Flame photometer; model C-140 after digesting 0.5 g sample with diacid mixture of HNO₃: HClO₄ in the ratio 4:1 as suggested by Jackson (1967).

3.12 Statistical analysis

The data collected on various growth, yield attributes, yield and quality parameters were statistically analyzed by using CPCS1 software developed by Department of Statistics, Punjab Agricultural University, Ludhiana based on the procedure of Cochran and Cox (1967) and adapted by Cheema and Singh (1991). All comparisons were made at 5 per cent level of significance. The degrees of freedom for randomized complete block design are given below:

Analysis of variance

Source of variation	Degree of freedom		
	Oilseed rape	Garden pea	Intercropping system
Replications (r-1)	3	3	3
Treatments (t-1)	11	10	13
Error (r-1) (t-1)	33	30	39
Total	47	43	55

CHAPTER IV

RESULTS AND DISCUSSION

The field experiment entitled “Productivity of oilseed rape (*Brassica napus* L.) and garden pea (*Pisum sativum* L.) intercropping system”, was carried out consecutively for two years at Students’ Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during *rabi* 2016-17 and 2017-18. The data recorded on different parameters of oilseed rape and garden pea have been presented and discussed under the following headings:

A. Oilseed rape

- 4.1 Plant growth parameters of oilseed rape
- 4.2 Phenology of oilseed rape
- 4.3 Yield attributes, yield and harvest index of oilseed rape
- 4.4 Quality parameters of oilseed rape

B. Garden pea

- 4.5 Plant growth parameters of garden pea
- 4.6 Yield attributes and yield of garden pea

C. Intercropping system analysis

- 4.7 Economic indices
- 4.8 Competitive indices
- 4.9 Plant analysis
- 4.10 Soil analysis

4.1 Plant growth parameters of oilseed rape

4.1.1 Plant height

Plant height is an important reliable index of plant growth at a given time during the growth period. Its measurement is often used to monitor the effect of different treatments on crop growth. The data on periodic plant height of oilseed rape recorded at 40, 80, 120 days after sowing (DAS) and at maturity are presented in table 6. The data indicated that there was progressive increase in plant height with advancement of crop age during both the years of study. A sharp increase in plant height was observed between 80 to 120 DAS which was considered to be the grand growth period. After 120 DAS, there was decline in the rate of increase in plant height. The data showed that up to 40 DAS, differences in plant height were recorded to be statistically at par among the different treatments. But at 80 DAS significantly higher plant height was recorded in flat sown GSC 7 + garden pea in 1:2 row ratio, statistically at par with flat sown GSC 7 + garden pea in 1:1 row ratio and sole GSC 7, during

Table 6: Periodic plant height of oilseed rape as influenced by different intercropping systems

Treatment	Plant height (cm)							
	2016-17				2017-18			
	40 DAS	80 DAS	120 DAS	At harvest	40 DAS	80 DAS	120 DAS	At harvest
GSC 6 (60cm, Fr) + GP (R) (1:1)	16.6	72.6	152.1	166.2	17.2	73.9	153.3	166.6
GSC 6 (60cm, F) + GP (F) (1:1)	17.5	75.8	154.7	166.1	18.4	74.6	155.3	169.8
GSC 6 (90cm, F) + GP (F) (1:2)	17.6	77.4	159.0	173.3	18.7	76.6	161.3	172.0
GSC 7 (60cm, Fr) + GP (R) (1:1)	19.1	96.2	182.7	196.5	19.9	93.4	181.4	196.9
GSC 7 (60cm, F) + GP (F) (1:1)	20.6	109.9	186.1	198.1	21.5	105.5	185.9	197.7
GSC 7 (90cm, F) + GP (F) (1:2)	22.1	111.1	186.6	198.4	22.9	106.6	187.1	198.5
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	20.0	93.0	174.8	188.2	20.1	89.6	174.1	188.0
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	22.5	95.3	174.2	188.3	21.9	95.2	175.0	189.4
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	22.1	99.8	175.4	192.0	22.4	95.9	177.1	191.3
Sole GSC 6 (30cm, F)	17.3	77.8	161.2	175.8	19.2	75.6	166.0	178.5
Sole GSC 7 (30cm, F)	22.3	109.3	176.1	188.1	22.4	105.4	176.1	188.2
Sole Hyola PAC 401 (30cm, F)	22.0	103.8	175.9	184.3	23.1	102.0	176.5	186.1
LSD (p=0.05)	NS	2.1	4.2	4.0	NS	3.4	6.0	2.5

NS=Non-significant, DAS= Days after sowing

both the years of study i.e., 2016-17 and 2017-18. At 120 DAS and at harvest the plant height of GSC 7 in different intercropping systems was statistically at par with each other but significantly better than all other treatments. This may be due to vigorous growth habit of GSC 7 in comparison to other cultivars of oilseed rape. Also, instead of wider row spacing available to oilseed rape, more intra row competition between plants in intercropping system resulted in higher plant height as compared to sole crop. Kumar and Singh (2006) and Singh *et al* (2010) also recorded significantly more plant height of Indian mustard when intercropped with chickpea as compared to sole crop of Indian mustard. Due to the varietal differences there were significant differences in plant height of cultivars during different growth stages. Thakur *et al* (2005) also reported that plant height of different genotypes were different because of their genetic constitution at different growth stages.

4.1.2 Dry Matter Accumulation (DMA)

DMA is one of most important parameter and it has marked influence on final yield realization of a crop. The optimum accumulation of dry matter followed by adequate partitioning of assimilates to the developing sinks enables the crop to attain its true yield potential. Data pertaining to DMA recorded at 40, 80, 120 DAS and at harvest are presented in table 7. The differences in the DMA were recorded to be statistically at par at 40 DAS during both the cropping seasons i.e. 2016-17 and 2017-18. But DMA by different cultivars differed significantly both in intercropping system as well as in sole crop stand at 80, 120 DAS and at harvest. At 80, 120 DAS and at harvest, maximum DMA was obtained in sole GSC 7 as compared to all other treatments. At 80 DAS this was statistically at par with flat sown GSC 7 + garden pea in 1:2 row ratio but at harvest it was statistically at par with flat sown sole Hyola PAC 401 during both the cropping seasons. This might be due to the varied growth pattern differences among the three cultivars. DMA was highest in GSC 7 based intercropping systems. In intercropping system, DMA was less as compared to sole crop which might be due to the presence of competition between main crop and intercrop for growth resources (nutrients, space, moisture, solar radiation). Mandal *et al* (1994) and Jana *et al* (1995) also reported that mustard accumulated higher amount of dry matter in its sole crop stand in comparison to its intercropping treatments due to absence of inter specific competition in sole crop of mustard. DMA by different cultivars varied in different intercropping treatments. Kumar *et al* (2001) also reported that dry matter accumulation varies with different genotypes.

4.1.3 Leaf Area Index (LAI)

LAI is an important parameter of growth which directly influences solar radiation interception by the canopy, photosynthesis and ultimately the yield of a crop. The LAI data presented in table 8 showed that differences in LAI were statistically at par at 40 DAS and at

Table 7: Periodic dry matter accumulation of oilseed rape as influenced by different intercropping systems

Treatment	Dry matter accumulation (q ha ⁻¹)							
	2016-17				2017-18			
	40 DAS	80 DAS	120 DAS	At harvest	40 DAS	80 DAS	120 DAS	At harvest
GSC 6 (60cm, Fr) + GP (R) (1:1)	1.2	14.7	68.1	84.9	1.0	14.1	66.5	81.5
GSC 6 (60cm, F) + GP (F) (1:1)	1.3	14.4	67.4	84.6	1.2	13.7	65.8	81.4
GSC 6 (90cm, F) + GP (F) (1:2)	1.2	14.8	69.6	86.3	1.2	14.6	68.5	84.4
GSC 7 (60cm, Fr) + GP (R) (1:1)	1.8	23.8	84.4	101.2	1.7	24.0	82.4	102.7
GSC 7 (60cm, F) + GP (F) (1:1)	1.9	24.0	83.4	102.2	1.8	23.9	81.2	101.9
GSC 7 (90cm, F) + GP (F) (1:2)	1.9	27.2	86.5	103.3	1.9	26.3	83.5	102.5
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	1.2	15.7	77.8	87.4	1.2	15.3	75.4	84.5
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	1.3	15.6	76.0	86.8	1.2	15.4	74.9	83.5
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	1.4	15.6	79.0	88.9	1.3	15.5	77.5	86.8
Sole GSC 6 (30cm, F)	1.3	15.3	82.1	91.2	1.2	15.0	80.7	88.8
Sole GSC 7 (30cm, F)	2.4	28.5	102.6	114.8	1.9	27.5	97.0	111.0
Sole Hyola PAC 401 (30cm, F)	1.4	16.5	88.1	104.3	1.3	16.2	85.8	103.0
LSD (p=0.05)	NS	4.4	10.3	11.4	NS	3.4	9.2	8.2

NS=Non-significant, DAS= Days after sowing

Table 8: Periodic leaf area index of oilseed rape as influenced by different intercropping systems

Treatment	Leaf area index							
	2016-17				2017-18			
	40 DAS	80 DAS	120 DAS	At harvest	40 DAS	80 DAS	120 DAS	At harvest
GSC 6 (60cm, Fr) + GP (R) (1:1)	1.15	3.33	3.58	1.00	1.22	3.21	3.30	1.15
GSC 6 (60cm, F) + GP (F) (1:1)	1.02	2.92	3.47	1.61	1.10	2.65	3.46	1.45
GSC 6 (90cm, F) + GP (F) (1:2)	1.35	3.75	3.64	1.25	1.37	3.72	3.51	1.62
GSC 7 (60cm, Fr) + GP (R) (1:1)	1.10	3.51	4.56	1.57	1.22	3.40	4.42	1.67
GSC 7 (60cm, F) + GP (F) (1:1)	1.42	3.47	4.47	1.75	1.45	3.37	4.43	1.60
GSC 7 (90cm, F) + GP (F) (1:2)	1.45	4.15	5.27	1.05	1.25	4.10	5.12	1.37
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	1.56	3.35	2.94	1.47	1.67	3.15	3.32	1.47
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	1.90	3.42	3.49	1.75	2.20	3.31	3.42	1.12
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	2.17	3.92	4.64	1.64	2.97	3.82	4.51	1.48
Sole GSC 6 (30cm, F)	1.07	3.75	3.95	1.32	1.15	3.75	3.93	1.22
Sole GSC 7 (30cm, F)	1.82	4.50	5.43	1.73	1.92	4.38	5.33	1.67
Sole Hyola PAC 401 (30cm, F)	1.65	4.07	4.95	1.82	1.65	4.01	4.78	1.45
LSD (p=0.05)	NS	0.6	0.7	NS	NS	0.8	0.6	NS

NS=Non-significant, DAS= Days after sowing

harvest during both the cropping seasons i.e. 2016-17 and 2017-18. At 80 and 120 DAS LAI was recorded to be highest in flat sown sole GSC 7 during both the years of study due to better spacial arrangement of plants in sole crop stand when compared to their arrangement in intercropping system. whereas, at 80 DAS LAI was statistically at par with flat sown GSC 7 + garden pea and flat sown Hyola PAC 401 + garden pea in 1:2 row ratio and flat sown sole Hyola PAC 401 during 2016-17 and it was statistically at par with flat sown GSC 6 + garden pea, flat sown GSC 7 + garden pea and flat sown Hyola PAC 401 + garden pea in 1:2 row ratio, flat sown sole GSC 6 and flat sown sole Hyola PAC 401 during 2017-18. But at 120 DAS, LAI was recorded to be statistically at par under flat sown GSC 7 + garden pea in 1:2 row ratio and flat sown sole Hyola PAC 401 during both the cropping seasons. In different intercropping treatments of oilseed rape with garden pea, LAI of oilseed rape was recorded to be higher in 1:2 row ratio when compared to their respective 1:1 row ratios. Due to wider row spacing (90 cm), better aeration and better solar radiation interception resulted in higher LAI in 1:2 row ratio. Sarkar *et al* (2011) also reported that rapeseed (*Brassica campestris*) attained highest LAI in sole crop than intercropping system due to absence of inter specific competition in sole crop.

4.1.4 Photosynthetically Active Radiation (PAR) interception

PAR interception and its distribution within the crop canopy is an important determinant of photosynthetic activity of crop. PAR interception by oilseed rape canopy influence the leaf photosynthesis efficiency, which in turn affects the dry matter production and grain yield. The data on PAR interception are presented in table 9. Different oilseed rape cultivars did not show any significant difference in PAR interception at 40 DAS during both the cropping seasons i.e., 2016-17 and 2017-18. At 80 and 120 DAS, flat sown sole GSC 7 recorded significantly higher PAR interception. This might be due to the absence of inter specific competition in sole crop stand of oilseed rape cultivars which provided congenial environment for growth of plants and thus resulting in higher interception of PAR. Whereas, among the different cultivars of oilseed rape, flat sown sole GSC 7 was found to intercept maximum solar radiations due to broader size of the leaves. At 80 and 120 DAS interception of PAR was statistically at par with flat sown GSC 7 + garden pea (1:2), flat sown sole GSC 6, sole Hyola PAC 401 during both the seasons. At harvest, there was no significant difference in PAR interception by different treatments due to senescence of leaves. Among the intercropping treatments of different cultivars of oilseed rape with garden pea PAR interception by oilseed rape cultivars was statistically higher in 1:2 row ratio when compared to their respective 1:1 row ratios.

Table 9: Periodic photosynthetically active radiation interception by oilseed rape as influenced by different intercropping systems

Treatment	Photosynthetically active radiation interception (%)							
	2016-17				2017-18			
	40 DAS	80 DAS	120 DAS	At harvest	40 DAS	80 DAS	120 DAS	At harvest
GSC 6 (60cm, Fr) + GP (R) (1:1)	54.0	72.0	85.3	51.3	52.9	72.0	86.4	51.0
GSC 6 (60cm, F) + GP (F) (1:1)	54.4	73.2	86.0	51.5	53.7	72.3	87.3	52.9
GSC 6 (90cm, F) + GP (F) (1:2)	56.5	77.4	89.8	55.5	55.9	76.1	91.1	54.8
GSC 7 (60cm, Fr) + GP (R) (1:1)	59.5	81.6	91.6	53.3	58.7	81.4	91.1	52.5
GSC 7 (60cm, F) + GP (F) (1:1)	59.9	82.4	92.7	55.1	60.0	81.6	92.5	52.0
GSC 7 (90cm, F) + GP (F) (1:2)	61.3	85.7	94.4	57.0	61.8	85.7	94.2	55.4
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	55.8	78.9	90.2	52.4	55.4	77.1	91.4	51.4
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	55.5	79.8	90.6	54.2	55.3	78.8	91.2	53.6
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	56.9	82.9	92.4	55.3	57.3	81.8	92.3	57.1
Sole GSC 6 (30cm, F)	67.6	83.6	93.8	56.1	66.0	83.3	93.7	55.7
Sole GSC 7 (30cm, F)	71.3	87.5	96.5	62.3	70.1	86.4	97.4	63.2
Sole Hyola PAC 401 (30cm, F)	67.9	84.3	94.7	57.4	65.1	83.3	94.3	56.9
LSD (p=0.05)	NS	4.2	3.1	NS	NS	3.7	4.2	NS

NS=Non-significant, DAS=Days after sowing



Plate 1: GSC 6 (60cm, Fr) + GP (R) (1:1)



Plate 2: GSC 6 (60cm, F) + GP (F) (1:1)



Plate 3: GSC 6 (90cm, F) + GP (F) (1:2)



Plate 4: Sole GSC 6 (30cm, F)



Plate 5: GSC 7 (60cm, Fr) + GP (R) (1:1)



Plate 6: GSC 7 (60cm, F) + GP (F) (1:1)



Plate 7: GSC 7 (90cm, F) + GP (F) (1:2)



Plate 8: Sole GSC 7 (30cm, F)



Plate 9: Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)



Plate 10: Hyola PAC 401 (60cm, F) + GP (F) (1:1)



Plate 11: Hyola PAC 401 (90cm, F) + GP (F) (1:2)



Plate 12: Sole Hyola PAC 401 (30cm, F)



Plate 13: Sole GP (60cm, R) at 40 DAS



Plate 14: Sole GP (30cm, F) 40 DAS

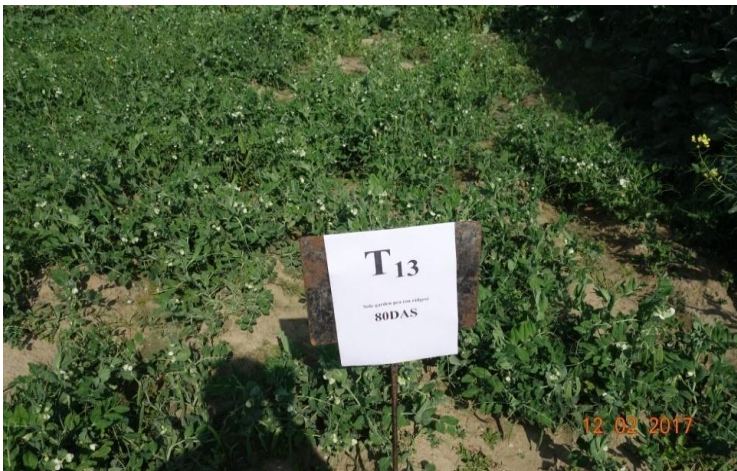


Plate 15: Sole GP (60cm, R) at 80 DAS



Plate 16: Sole GP (30cm, F) 80 DAS

4.2 Phenological observations

4.2.1 Days taken to 50 per cent seedling emergence

Crop emergence is pre-requisite for obtaining optimum plant population, which ultimately contributes to crop yield. Time taken for emergence by crop cultivar reflects the relative pace of growth and its ability to perform better under prevailing edaphic and environmental conditions. In order to assess the effect of different treatments particularly cultivars and intercropping systems on crop stand, plant count was recorded periodically. (Table 10). The days taken for 50 per cent emergence of oilseed rape varied between 6.2 to 6.4 and 6.3 to 6.5 days during 2016-17 and 2017-18, respectively under different treatments. However, the differences in days taken to 50 per cent seedling emergence were recorded to be statistically similar under different cultivars of oilseed rape and intercropping systems.

4.2.2 Days taken to 50 per cent flowering

Flowering is a genotypic character and is seldom influenced by intercropping. The data pertaining to days taken to 50 per cent flowering is presented in table 10 and there were no significant differences among the different treatments with respect to days to 50 per cent flowering during both the seasons. Days taken to 50 per cent flowering varied between 64.3 to 69.5 and 64.6 to 69.3 during 2016-17 and 2017-18, respectively.

4.2.3 Days taken to 50 per cent siliquae formation

Siliquae indicates the seed formation stage of the crop. The data pertaining to days taken to 50 per cent siliquae formation are presented in table 10. Differences in number of days taken to 50 per cent siliquae formation among different treatments were statistically at par. Days to 50 per cent siliquae formation varied from 81.2 to 86.5 and 82.3 to 87.5 during 2016-17 and 2017-18, respectively.

4.2.4 Physiological maturity

Different oilseed rape cultivars and intercropping systems did not significantly influence the physiological maturity (Table 10). However, days taken to maturity varied from 141.0 to 143.0 and 143.0 to 145.0 under different treatments during 2016-17 and 2017-18, respectively.

4.3 Yield attributes, yield and harvest index of oilseed rape

4.3.1 Number of primary and secondary branches

Plant architecture including branching is a genetic character but it is also influenced by environmental variables and management practices. Higher number of branches per plant may support more number of siliquae per plant and consequently contribute to seed yield. Competition for growth resources as well as for space may result in restricted growth of plants. This effect was more pronounced in narrow row spacing than wider row spacing. Differences in the production of primary and secondary branches by different treatments were statistically at par during both the cropping seasons of 2016-17 and 2017-18 (Table 11). The production of

Table 10: Phenological stages of oilseed rape as influenced by different intercropping systems

Treatment	Days taken to							
	50 % emergence		50 % flowering		50% siliquae formation		Physiological maturity	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
GSC 6 (60cm, Fr) + GP (R) (1:1)	6.2	6.3	64.3	64.6	81.2	82.4	141.0	143.0
GSC 6 (60cm, F) + GP (F) (1:1)	6.2	6.3	64.5	64.6	81.2	82.3	141.0	143.0
GSC 6 (90cm, F) + GP (F) (1:2)	6.2	6.3	64.6	64.9	81.3	82.4	141.0	143.0
GSC 7 (60cm, Fr) + GP (R) (1:1)	6.4	6.5	65.3	65.4	83.0	85.3	141.0	143.0
GSC 7 (60cm, F) + GP (F) (1:1)	6.4	6.5	65.3	65.4	83.3	85.4	141.0	143.0
GSC 7 (90cm, F) + GP (F) (1:2)	6.3	6.5	65.7	65.6	83.0	85.4	141.0	143.0
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	6.4	6.3	68.5	68.1	86.5	87.5	143.0	145.0
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	6.4	6.3	68.5	68.3	86.3	87.3	143.0	145.0
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	6.4	6.3	68.5	68.7	86.5	87.4	143.0	145.0
Sole GSC 6 (30cm, F)	6.4	6.3	65.7	65.5	81.3	82.3	141.0	143.0
Sole GSC 7 (30cm, F)	6.4	6.5	67.4	67.3	83.0	85.4	141.0	143.0
Sole Hyola PAC 401 (30cm, F)	6.4	6.4	69.5	69.3	86.4	87.4	143.0	145.0
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS=Non- significant

Table 11: Number of primary and secondary branches of oilseed rape as influenced by different intercropping systems

Treatment	Primary branches (No.)		Secondary branches (No.)	
	2016-17	2017-18	2016-17	2017-18
GSC 6 (60cm, Fr) + GP (R) (1:1)	5.0	5.0	7.5	7.4
GSC 6 (60cm, F) + GP (F) (1:1)	4.7	4.5	7.4	7.3
GSC 6 (90cm, F) + GP (F) (1:2)	4.5	5.2	7.6	7.5
GSC 7 (60cm, Fr) + GP (R) (1:1)	6.0	5.5	7.8	7.7
GSC 7 (60cm, F) + GP (F) (1:1)	5.5	5.2	7.6	7.5
GSC 7 (90cm, F) + GP (F) (1:2)	5.2	5.2	8.4	8.2
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	6.0	6.0	7.6	7.5
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	5.0	5.2	7.5	7.5
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	5.2	5.5	8.2	8.1
Sole GSC 6 (30cm, F)	4.5	5.0	7.7	7.6
Sole GSC 7 (30cm, F)	5.7	5.5	8.5	8.3
Sole Hyola PAC 401 (30cm, F)	5.0	5.7	8.2	8.1
LSD (p=0.05)	NS	NS	NS	NS

NS= Non-significant

primary branches by different treatments ranged from 4.5 to 6 during both the cropping seasons. Whereas, production of secondary branches varied from 7.4 to 8.5 and 7.3 to 8.3 during 2016-17 and 2017-18, respectively.

4.3.2 Number of siliquae per plant

Number of siliquae per plant is considered as a major yield contributing parameter in rapeseed-mustard crop. Siliquae formation is an inherent character and is also influenced by branching and agronomic practices. However, plant bears siliquae due to its higher number of primary and secondary branches per plant. There was no significant difference in number of siliquae per plant by different treatments of oilseed rape. Number of siliquae produced per plant varied between 312.1 to 414.6 in 2016-17 and 322.7 to 405.1 in 2017-18 (Table 12).

4.3.3 Number of seeds per siliqua

Number of seeds per siliqua depends on length of siliqua and is generally negatively correlated with number of siliquae per plant i.e. more the number of siliquae per plant, lesser the length of siliqua and number of seeds per siliqua. There was no significant difference in production of seeds per siliquae by different cultivars in both intercropping and sole crop treatments, during both the cropping seasons (Table 12). Number of seeds per siliqua produced by different cultivars in intercropping system and sole crop varied between 16.0 to 18.2.

4.3.4 1000-seed weight

Seed size is often influenced by the period available for seed development. Thousand seed weight was not significantly influenced by different intercropping treatments during both the cropping seasons. Thousand seed weight of different cultivars of oilseed rape varied from 3.32 to 3.85 g and 3.41 to 4.00 g, during 2016-17 and 2017-18, respectively (Table 12).

4.3.5 Seed yield

The ultimate objective of all the agronomic studies is to optimize the yield of the crop. The economic yield of crop depends on the manner in which the dry matter production takes place during vegetative phase of crop and its distribution to various sinks i.e. the vegetative and reproductive parts. Therefore, the seed yield of crop is net resultant of interaction of various factors and is a valid criterion for comparing the efficiency of different treatments. The data on seed yield of oilseed rape was recorded and presented in table 13 and fig 4. There was no significant difference in the seed yield of different cultivars of oilseed rape during both the growing seasons of 2016-17 and 2017-18. Whereas, seed yield was comparatively higher in sole crop stand of different cultivars of oilseed rape. Higher yield of oilseed rape in sole crop stand may be attributed to less competition and production of higher number of secondary branches, siliquae per plant, seeds per siliqua and thousand seed weight. Singh *et al* (2000) and Devi *et al* (2014) also reported higher mustard yield in the sole crop stand. The pooled analysis of seed yield data also revealed the similar trend.

Table 12: Yield attributing characters of oilseed rape as influenced by different intercropping systems

Treatment	Siliquae per plant (No.)		Seeds per siliqua (No.)		1000 seed weight (g)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
GSC 6 (60cm, Fr) + GP (R) (1:1)	336.0	335.0	16.0	16.0	3.32	3.41
GSC 6 (60cm, F) + GP (F) (1:1)	332.7	342.8	16.0	16.1	3.36	3.45
GSC 6 (90cm, F) + GP (F) (1:2)	312.1	322.7	16.1	16.0	3.38	3.52
GSC 7 (60cm, Fr) + GP (R) (1:1)	390.7	370.6	18.0	18.0	3.72	3.84
GSC 7 (60cm, F) + GP (F) (1:1)	389.8	384.5	18.1	18.1	3.76	4.00
GSC 7 (90cm, F) + GP (F) (1:2)	369.0	355.6	18.1	18.2	3.81	3.82
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	398.3	393.1	17.0	17.0	3.53	3.68
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	387.6	389.8	17.0	17.1	3.57	3.67
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	364.2	374.2	17.2	17.2	3.61	3.74
Sole GSC 6 (30cm, F)	341.6	397.3	16.2	16.2	3.38	3.54
Sole GSC 7 (30cm, F)	398.4	391.0	18.2	18.2	3.85	3.90
Sole Hyola PAC 401 (30cm, F)	414.6	405.1	17.1	17.2	3.62	3.64
LSD (p=0.05)	NS	NS	NS	NS	NS	NS

NS= Non-significant

Table 13: Seed and stover yield of oilseed rape as influenced by different intercropping systems

Treatment	Seed yield (q ha ⁻¹)			Stover yield (q ha ⁻¹)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
GSC 6 (60cm, Fr) + GP (R) (1:1)	17.7	16.8	17.3	61.6	61.1	61.4
GSC 6 (60cm, F) + GP (F) (1:1)	17.6	15.0	16.3	63.1	62.6	62.9
GSC 6 (90cm, F) + GP (F) (1:2)	17.7	15.0	16.4	61.1	60.7	60.9
GSC 7 (60cm, Fr) + GP (R) (1:1)	18.1	18.3	18.2	75.8	73.2	74.5
GSC 7 (60cm, F) + GP (F) (1:1)	19.6	18.2	18.9	76.5	71.5	74.0
GSC 7 (90cm, F) + GP (F) (1:2)	19.1	17.4	18.3	79.1	72.6	75.9
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	20.0	17.6	18.8	79.6	77.8	78.7
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	19.6	17.0	18.3	78.9	76.0	77.5
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	19.7	16.5	18.1	71.9	70.4	71.2
Sole GSC 6 (30cm, F)	18.4	17.7	18.1	73.9	72.6	73.3
Sole GSC 7 (30cm, F)	19.8	19.5	19.7	84.7	87.3	86.0
Sole Hyola PAC 401 (30cm, F)	20.2	17.8	19.0	86.1	84.8	85.5
LSD (p=0.05)	NS	NS	NS	5.9	6.6	4.3

NS=Non-significant

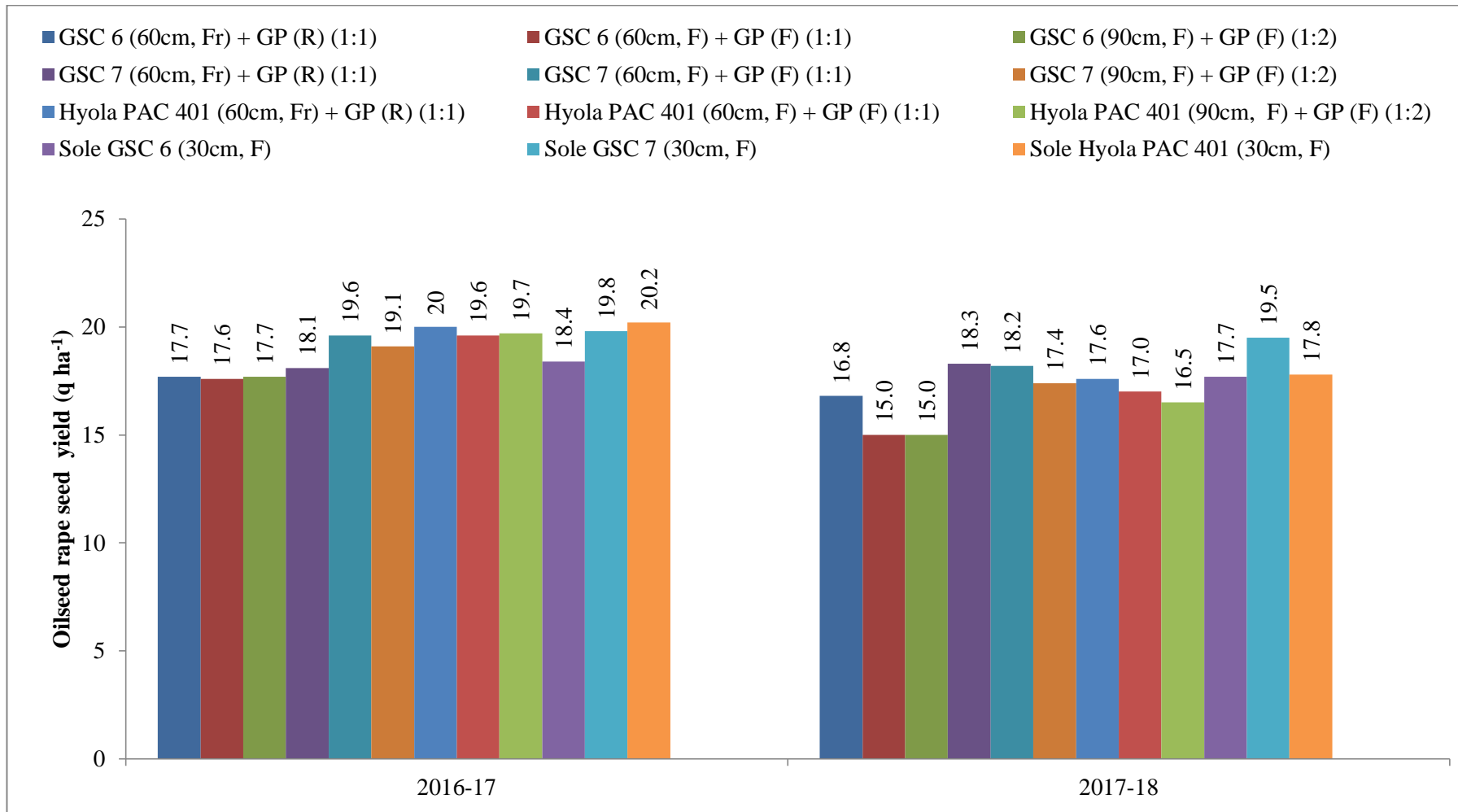


Fig 4: Oilseed rape seed yield as influenced by different intercropping systems during 2016-17 and 2017-18

4.3.6 Stover yield

The data on stover yield are presented in table 13. There was significant difference in the production of stover yield by oilseed rape. Stover production by oilseed rape varied between 61.1 to 86.1 q ha⁻¹ and 61.1 to 87.3 q ha⁻¹ during 2016-17 and 2017-18, respectively. The stover yield of flat sown sole Hyola PAC 401 and flat sown sole GSC 7 were statistically at par with each other and significantly better than all other treatments. Similar trend was noticed in the pooled analysis of stover yield. Devi *et al* (2014) also reported higher stover yield of mustard in sole crop stand and relatively lower stover yield of mustard in intercropping treatments.

4.3.7 Biological yield

Generally when nutrients and water are not limiting, production of dry matter is determined by the amount of solar radiation in the crop canopy. Dry matter production by the crop depends upon the amount of photosynthetic active radiation absorbed by the leaves and its efficiency of conversion in to chemical energy. Otherwise, the amount of absorbed radiation depends on efficiency of interception of solar radiation by leaves as reported by Begamaschi *et al* (2010). Biological yield production by oilseed rape showed significant differences during the cropping seasons of 2016-17 and 2017-18 (Table 14). Flat sown sole Hyola PAC 401 and GSC 7 produced statistically similar biological yield but significantly better than all the treatments. Higher number of rows in sole canola cultivars and free environment due to lack of inter-specific competition might be the reasons for higher biological yield when compared to their intercropping treatments. Similar results with respect to biological yield were observed by Khan *et al* (2012), Tahir *et al* (2003) and Imran *et al* (2011). The pooled analysis of biological yields of both the cropping seasons also revealed same results.

4.3.8 Harvest index

Harvest index is an important parameter indicating the efficiency of partitioning of dry matter to economic parts of the crop. Higher value of harvest index indicates that plant is more efficient in producing economic yield. The data on harvest index of crop during both the seasons of 2016-17 and 2017-18 are represented in table 14. The differences among the harvest index of different treatments were recorded to be statistically at par during both the cropping seasons.

Table 14: Biological yield and harvest index of oilseed rape as influenced by different intercropping systems

Treatment	Biological yield (q ha ⁻¹)			Harvest index (%)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
GSC 6 (60cm, Fr) + GP (R) (1:1)	79.3	77.8	78.6	22.3	21.6	22.0
GSC 6 (60cm, F) + GP (F) (1:1)	80.8	77.6	79.2	22.0	19.5	20.8
GSC 6 (90cm, F) + GP (F) (1:2)	78.8	75.8	77.3	22.4	19.8	21.1
GSC 7 (60cm, Fr) + GP (R) (1:1)	93.9	91.5	92.7	19.1	20.0	19.6
GSC 7 (60cm, F) + GP (F) (1:1)	96.1	89.7	92.9	20.3	20.2	20.3
GSC 7 (90cm, F) + GP (F) (1:2)	98.2	90.0	94.1	19.5	19.4	19.4
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	99.7	95.4	97.6	20.1	18.4	19.3
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	98.4	93.0	95.7	19.8	18.3	19.1
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	91.6	86.9	89.3	21.5	18.9	20.2
Sole GSC 6 (30cm, F)	92.3	90.2	91.3	19.9	19.7	19.8
Sole GSC 7 (30cm, F)	104.5	106.8	105.7	18.9	18.3	18.6
Sole Hyola PAC 401 (30cm, F)	106.3	102.5	104.4	19.0	17.3	18.1
LSD (p=0.05)	6.1	7.4	4.7	NS	NS	NS

NS=Non-significant

4.4 Quality parameters of oilseed rape

4.4.1 Oil content and oil yield of oilseed rape

The data pertaining to oilseed rape seed oil content (%) and yield is presented in table 15. Seed oil content was not affected significantly by different intercropping systems. Seed oil content varied from 38.3 to 41.1 per cent and 38.7 to 41.1 per cent during both the cropping seasons. Sharma and Khushwaha (2012) also recorded that seed oil content was not significantly influenced by intercropping of Indian mustard with chickpea in varying row proportions. Oil yield also showed the same trend.

4.4.2 Seed protein content and protein yield

Seed protein content (%) and protein yield of oilseed rape are presented in table 15. There were no significant differences in protein content and protein yield of oilseed rape. The seed protein content varied between 14.1 to 16.5 per cent and 14.2 to 16.4 per cent during 2016-17 and 2017-18 respectively. Malhi (2012) also observed higher protein concentration in oilseed rape when it was intercropped with pea. Oilseed rape protein yield data also revealed that protein yield of oilseed rape was not significantly influenced by different intercropping systems.

B. Garden pea

4.5 Plant growth parameters of garden pea

4.5.1 Plant height

The data given in table 16 revealed that, the differences in plant height of garden pea at 40 DAS were statistically at par during both the cropping seasons i.e. 2016-17 and 2017-18. Flat sown sole garden pea recorded highest plant height at 80 DAS and at harvest and it was statistically at par with ridge sown sole garden pea during both the cropping seasons. Among the intercropping treatments, garden pea intercropped with oilseed rape in 1:2 row ratio recorded statistically higher plant height at 80 DAS and it was at par with their respective 1:1 row ratios. At harvest, plant height of garden pea intercropped with different cultivars of oilseed rape was recorded to be significantly higher in their respective 1:2 row ratios.

4.5.2 Dry Matter Accumulation (DMA)

The differences in garden pea DMA were found to be statistically at par at 40 DAS during both the seasons i.e. 2016-17 and 2017-18 (Table 17). DMA was recorded to be highest in ridge sown sole garden pea at 80 DAS and at harvest. It was statistically at par with flat sown sole garden pea only, during both the cropping seasons. Among the different intercropping treatments, DMA by garden pea was significantly higher in 1:2 row ratio and statistically at par with 1:1 row ratios. It might be due to the wider space available to garden pea in 1:2 row ratio as compared to their respective 1:1 row ratios.

Table 15: Quality parameters of oilseed rape as influenced by different intercropping systems

Treatment	Oil content (%)		Oil yield (q ha ⁻¹)		Protein content (%)		Protein yield (q ha ⁻¹)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
GSC 6 (60cm, Fr) + GP (R) (1:1)	38.3	38.7	6.80	6.50	15.9	15.8	2.70	2.70
GSC 6 (60cm, F) + GP (F) (1:1)	39.2	39.3	6.90	5.90	15.8	15.8	2.70	2.70
GSC 6 (90cm, F) + GP (F) (1:2)	39.6	39.9	7.00	6.00	16.0	15.9	2.70	2.70
GSC 7 (60cm, Fr) + GP (R) (1:1)	38.9	39.0	7.00	7.10	16.4	16.2	2.90	2.90
GSC 7 (60cm, F) + GP (F) (1:1)	39.3	39.1	7.70	7.10	16.2	16.1	3.10	3.10
GSC 7 (90cm, F) + GP (F) (1:2)	39.6	39.7	7.60	6.90	16.5	16.4	3.10	3.10
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	40.0	40.1	8.00	7.10	15.9	15.8	3.10	3.10
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	40.6	40.5	7.90	6.90	15.8	15.4	3.00	3.00
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	41.1	41.1	8.10	6.80	16.0	15.9	3.10	3.10
Sole GSC 6 (30cm, F)	38.6	38.8	7.10	6.80	14.1	14.2	2.50	2.50
Sole GSC 7 (30cm, F)	39.7	39.7	7.80	7.80	14.4	14.3	2.80	2.80
Sole Hyola PAC 401 (30cm, F)	40.2	40.3	8.10	7.10	14.2	14.2	2.80	2.80
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS=Non-significant

Table 16: Periodic plant height of garden pea as influenced by different intercropping systems

Treatment	Plant height (cm)					
	2016-17			2017-18		
	40 DAS	80 DAS	At harvest	40 DAS	80 DAS	At harvest
GSC 6 (60cm, Fr) + GP (R) (1:1)	22.57	60.20	73.21	21.52	63.88	75.01
GSC 6 (60cm, F) + GP (F) (1:1)	22.00	61.90	75.76	25.58	63.50	76.82
GSC 6 (90cm, F) + GP (F) (1:2)	22.82	66.35	83.80	23.41	69.25	84.82
GSC 7 (60cm, Fr) + GP (R) (1:1)	24.65	62.67	74.28	22.66	63.90	74.82
GSC 7 (60cm, F) + GP (F) (1:1)	23.27	63.42	75.70	26.07	64.25	74.56
GSC 7 (90cm, F) + GP (F) (1:2)	25.20	64.50	81.74	26.41	65.87	83.28
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	26.65	61.60	74.55	24.38	64.87	74.01
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	23.70	61.90	77.13	26.73	65.30	76.35
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	25.95	66.10	84.82	24.10	67.77	83.75
Sole GP (60cm, R)	23.42	68.70	88.75	22.26	69.78	85.73
Sole GP (30cm, F)	24.90	72.77	90.83	26.82	76.12	89.58
LSD (p=0.05)	NS	6.3	4.8	NS	6.6	3.9

NS= Non-significant, DAS= Days after sowing

Table 17: Periodic dry matter accumulation by garden pea as influenced by different intercropping systems

Treatment	Dry matter accumulation (g plant ⁻¹)					
	2016-17			2017-18		
	40 DAS	80 DAS	At harvest	40 DAS	80 DAS	At harvest
GSC 6 (60cm, Fr) + GP (R) (1:1)	0.48	7.48	10.65	0.53	7.54	11.77
GSC 6 (60cm, F) + GP (F) (1:1)	0.46	7.48	10.14	0.50	7.48	11.41
GSC 6 (90cm, F) + GP (F) (1:2)	0.53	7.56	11.20	0.54	7.86	12.58
GSC 7 (60cm, Fr) + GP (R) (1:1)	0.52	6.08	9.51	0.48	7.20	10.37
GSC 7 (60cm, F) + GP (F) (1:1)	0.45	6.88	9.31	0.43	7.13	9.89
GSC 7 (90cm, F) + GP (F) (1:2)	0.57	7.38	10.85	0.57	7.38	11.84
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	0.51	7.55	12.03	0.51	8.35	12.35
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	0.53	7.50	11.77	0.50	8.11	12.07
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	0.63	7.69	12.15	0.57	8.56	12.68
Sole GP (60cm, R)	0.68	9.82	14.65	0.53	10.86	15.61
Sole GP (30cm, F)	0.66	8.85	13.67	0.50	9.88	14.77
LSD (p=0.05)	NS	1.31	1.43	NS	1.42	1.43

NS= Non-significant, DAS= Days after sowing

4.6 Yield attributes and yield of garden pea

4.6.1 Number of pods per plant

Pod number is an important index of pod yield. The data on number of pods per plant is presented in table 18. Statistically there was significant difference in number of pods per plant of garden pea. Ridge sown sole garden pea (60cm) produced significantly higher numbers of pods per plant during both the growing seasons of 2016-17 and 2017-18. Among the different intercropping treatments, garden pea intercropped with GSC 7 in different row proportions produced lower number of pods per plant when compared to pod production in intercropping systems of GSC 6 and Hyola PAC 401 during both the cropping seasons. Awal *et al* (2007) and Singh *et al* (2000) also recorded higher number of pods per plant of soybean and lentil in sole crop stand as compared to their number in intercropping system.

4.6.2 Number of seeds per pod

The data pertaining to seeds per pod (Table 18) revealed that there was no significant difference in production of seeds per pod by garden pea among all the treatments, but it varied between 6.8 to 9.0 during 2016-17 and 7.3 to 9.2 during 2017-18.

4.6.3 100-seed weight

The data on 100 seed weight of garden pea (Table 18) revealed that there was no significant difference in 100 seed weight of garden peas in both sole and among different intercropping treatments during both growing seasons of 2016-17 and 2017-18. But it ranged between 30.8 g to 33.7 g during 2016-17 and 31.4 g to 36.4 g during 2017-18.

4.6.4 Green pod yield

Final yield of crop reflects the ultimate effect of any experimental variable. The data on garden pea yield during cropping seasons of 2016-17 and 2017-18 are presented in table 19 which indicates that sole crop stands of garden peas produced significantly higher yield than in intercropping systems. Among the sole crop stands of garden peas, flat sown sole pea produced highest green pod yield which was significantly higher than all other treatments during both the years. Higher yield obtained was the resultant of higher plant population in flat sown sole garden pea. Among the intercropping treatments, different cultivars of oilseed rape intercropped with garden pea in 1:2 row ratio recorded higher garden pea green pod yield as compared to 1:1 row ratio but the differences were not significant. Awal *et al* (2007) recorded soybean performing better in double row intercropping than in single row intercropping with Indian mustard. Higher yields of component crops in wider spatial patterns of intercropping systems have been reported by many workers (Singh 1981, Tarharkar and Rao 1981, Waghmare *et al* 1982).

Table 18: Yield attributes of garden pea as influenced by different intercropping systems

Treatment	Pods per plant (No.)		Seeds per pod (No.)		100 seed weight (g)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
GSC 6 (60cm, Fr) + GP (R) (1:1)	25.0	30.7	7.2	7.5	31.1	31.6
GSC 6 (60cm, F) + GP (F) (1:1)	23.4	31.8	7.1	7.8	31.4	31.5
GSC 6 (90cm, F) + GP (F) (1:2)	29.3	32.7	7.0	7.3	31.6	31.8
GSC 7 (60cm, Fr) + GP (R) (1:1)	17.6	22.1	6.2	6.3	31.2	31.4
GSC 7 (60cm, F) + GP (F) (1:1)	17.8	20.6	6.2	6.3	30.8	31.6
GSC 7 (90cm, F) + GP (F) (1:2)	19.1	24.4	6.2	6.3	31.8	31.8
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	26.1	32.7	7.1	7.8	31.7	31.8
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	25.0	31.9	6.9	6.0	31.5	31.8
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	28.0	32.6	7.3	8.0	32.6	31.6
Sole GP (60cm, R)	40.5	46.8	8.7	8.8	32.5	35.5
Sole GP (30cm, F)	34.1	38.3	9.0	9.2	33.7	36.4
LSD (p=0.05)	2.31	2.61	NS	NS	NS	NS

NS= Non-significant

Table 19: Green pod yield of garden pea as influenced by different intercropping systems

Treatment	Green pod yield (q ha ⁻¹)		
	2016-17	2017-18	Pooled
GSC 6 (60cm, Fr) + GP (R) (1:1)	21.0	27.0	24.0
GSC 6 (60cm, F) + GP (F) (1:1)	23.8	27.6	25.7
GSC 6 (90cm, F) + GP (F) (1:2)	25.1	32.3	28.7
GSC 7 (60cm, Fr) + GP (R) (1:1)	18.6	28.5	23.6
GSC 7 (60cm, F) + GP (F) (1:1)	16.1	24.4	20.3
GSC 7 (90cm, F) + GP (F) (1:2)	20.0	31.9	26.0
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	23.1	27.1	25.1
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	23.0	27.8	25.4
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	25.4	32.4	28.9
Sole GP (60cm, R)	129.8	172.5	151.2
Sole GP (30cm, F)	150.9	187.5	169.2
LSD (p=0.05)	12.3	4.9	9.14

NS= Non significant

There was significant reduction in green pod yield among intercropping treatments as compared to their sole crop yield. Banik *et al* (2000) also reported higher yield of pea from its sole crop stand. Kanwar *et al* (1998) and Singh *et al* (1986) also reported significant reduction in yield of component crop in comparison to its sole crop yield stand as compared to intercropping systems. Increase in garden pea yield during the cropping season 2017-18 may be due to favourable climatic conditions such as temperature, optimum rainfall and sunshine hours which were congenial for growth of garden peas. Similar results were obtained in pooled analysis.

C. Intercropping system analysis

4.7 Economic analysis

4.7.1 Oilseed rape equivalent yield

The data pertaining to oilseed rape equivalent yield is presented in table 20 and fig 5. Flat sown sole garden pea recorded significantly higher equivalent yield of oilseed rape during both the cropping seasons of 2016-17 and 2017-18. This is due to the fact that, garden pea is short duration, fast growing legume crop having higher yield potential under favourable climatic conditions, moisture, nutrients and absence of competition. Significantly higher equivalent yields of oilseed rape were recorded in different intercropping systems with garden

Table 20: Oilseed rape equivalent yield and system productivity as influenced by different intercropping systems

Treatment	Oilseed rape equivalent yield (q ha ⁻¹)			System productivity (kg ha ⁻¹ day ⁻¹)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
GSC 6 (60cm, Fr) + GP (R) (1:1)	22.4	22.5	22.5	15.9	15.7	15.8
GSC 6 (60cm, F) + GP (F) (1:1)	23.0	20.9	22.0	16.3	14.6	15.5
GSC 6 (90cm, F) + GP (F) (1:2)	23.3	21.9	22.6	16.5	15.3	15.9
GSC 7 (60cm, Fr) + GP (R) (1:1)	22.3	24.3	23.3	15.8	17.0	16.4
GSC 7 (60cm, F) + GP (F) (1:1)	23.2	23.4	23.3	16.4	16.3	16.4
GSC 7 (90cm, F) + GP (F) (1:2)	23.6	24.2	23.9	16.8	16.9	16.9
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	25.2	23.4	24.3	17.6	16.1	16.9
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	24.7	22.9	23.8	17.3	15.8	16.6
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	25.4	23.4	24.4	17.8	16.1	17.0
Sole GSC 6 (30cm, F)	18.4	17.7	18.1	13.0	12.4	12.7
Sole GSC 7 (30cm, F)	19.8	19.5	19.7	14.0	13.6	13.8
Sole Hyola PAC 401 (30cm, F)	20.2	17.8	19.0	14.1	12.3	13.2
Sole GP (60cm, R)	29.1	36.7	32.9	25.8	31.9	28.9
Sole GP (30cm, F)	33.8	39.8	36.8	30.0	34.7	32.4
LSD (p=0.05)	4.21	3.11	2.6	3.2	2.2	2.7

MSP – Oil seed rape (2017- ₹ 3700 q⁻¹, 2018- ₹ 4000 q⁻¹), Garden pea (2017- ₹ 830 q⁻¹, 2018- ₹ 850 q⁻¹)

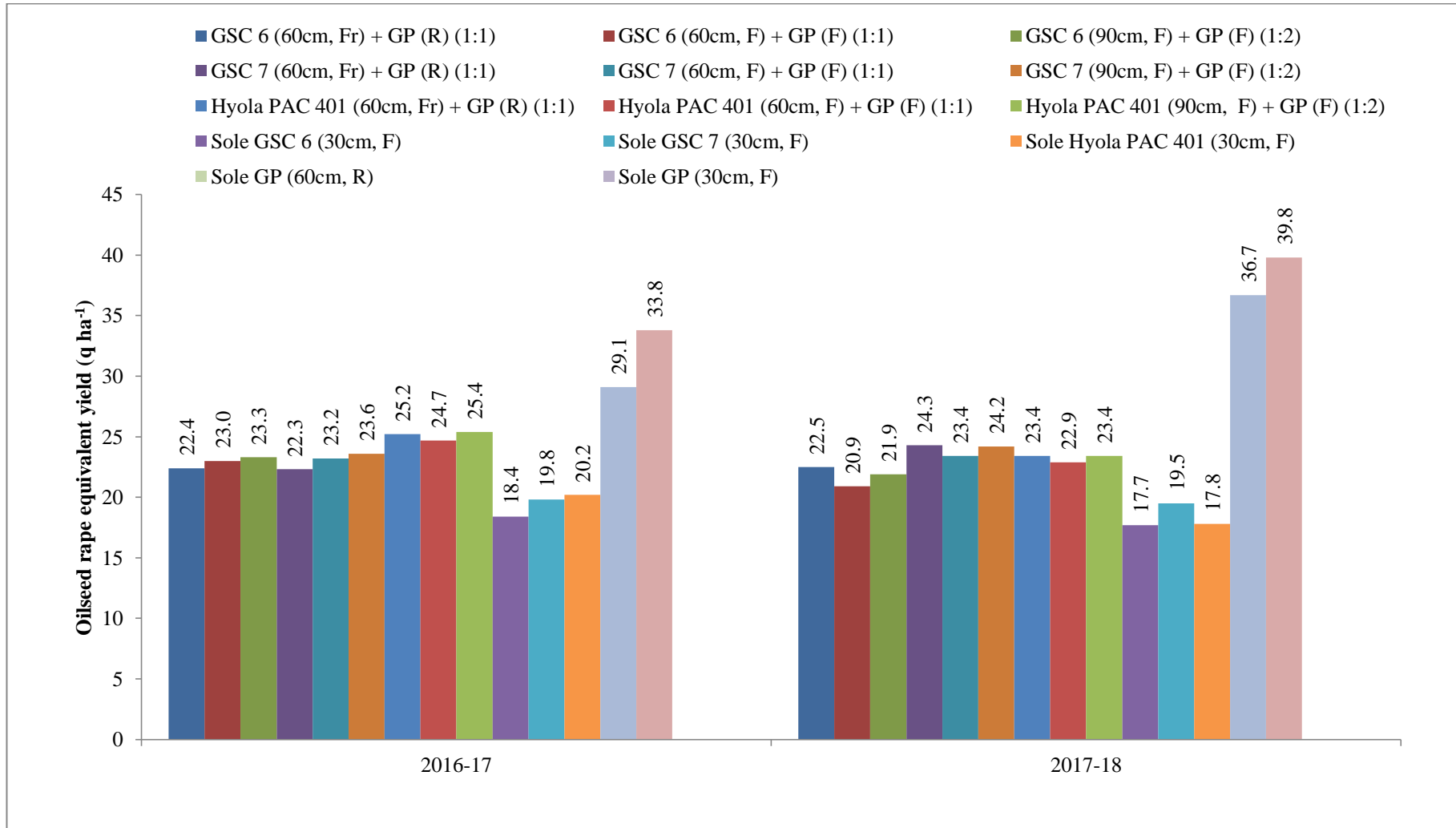


Fig. 5: Oilseed rape equivalent yield as influenced by different intercropping systems during 2016-17 and 2017-18

pea as compared to the sole crop stands of different cultivars of oilseed rape. Sharma and Kushwaha (2012) also reported increase in Indian mustard equivalent yield with intercropping as compared to the sole crop stand. The pooled analysis of oilseed rape equivalent yield data also revealed the same results. Among the intercropping systems, the maximum oilseed rape equivalent yield was obtained in Hyola PAC 401+ garden pea in 1:2 row ratio (24.4 q ha⁻¹) and the minimum was obtained in flat sown GSC 6 + garden pea in 1:1 row ratio (22.0 q ha⁻¹).

4.7.2 System productivity

The data on system productivity of the study have been presented in table 20. System productivity was recorded to be significantly higher for flat sown sole garden pea. Whereas, significantly higher system productivity was recorded for all the oilseed rape and garden pea based intercropping systems as compared to sole oilseed rape stands during both the cropping seasons. Similar results were obtained in the pooled analysis.

4.7.3 Gross returns

The data recorded on gross returns are given in table 21. Flat sown sole garden pea recorded higher gross returns among all the treatments due to its higher potential yield during both the cropping seasons of 2016-17 and 2017-18. All the oilseed rape based intercropping systems resulted in higher gross returns when compared to their gross return in sole crop stand. This is due to the additional yield of component crop i.e. garden pea of the intercropping systems. Kumar *et al* (2009) also reported that intercropping of chickpea + Indian mustard resulted in highest gross returns than sole crop of chickpea and sole crop of Indian mustard. Similar trend was followed by mean of data of both the years. Among the different intercropping systems maximum gross returns were obtained from flat sown Hyola PAC 401+ garden pea in 1:2 row ratio followed by furrow sown Hyola PAC 401 + ridge sown garden pea in 1:1 row ratio and flat sown GSC 7 + garden pea in 1:2 row ratio and minimum was recorded in flat sown GSC 6 + garden pea in 1:1.

4.7.4 Net returns

The data recorded on net returns are given in table 21 and fig 6 and the data revealed that, flat sown sole garden pea gave higher net returns during 2016-17 and 2017-18. Different oilseed rape based intercropping systems resulted in higher net returns and further these were higher than that obtained in sole crop stands. This is due to the additional yield of component crops in the intercropping systems. Sharma and Kushwaha (2012) also obtained higher net returns from intercropping system *viz.*, chickpea + Indian mustard in 3:1, 4:1 and 6:1 row ratios as compared to their sole stands. Also Potato + Indian mustard intercropping in 2:1 row ratio

Table 21: Gross returns, net returns and Benefit Cost ratio (B: C) of different oilseed rape based intercropping systems

Treatment	Gross returns ($\times 10^3 \text{ ₹ ha}^{-1}$)			Net returns ($\times 10^3 \text{ ₹ ha}^{-1}$)			B: C		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
GSC 6 (60cm, Fr) + GP (R) (1:1)	82.9	89.9	86.4	40.7	35.2	38.0	1.74	1.83	1.78
GSC 6 (60cm, F) + GP (F) (1:1)	85.0	83.6	84.3	34.4	37.3	35.9	1.78	1.70	1.74
GSC 6 (90cm, F) + GP (F) (1:2)	86.2	87.5	86.9	38.3	38.0	38.2	1.79	1.78	1.78
GSC 7 (60cm, Fr) + GP (R) (1:1)	82.4	97.4	89.9	48.2	34.7	41.4	1.73	1.98	1.85
GSC 7 (60cm, F) + GP (F) (1:1)	85.7	93.4	89.6	44.2	38.0	41.1	1.80	1.90	1.85
GSC 7 (90cm, F) + GP (F) (1:2)	87.5	96.8	92.1	47.6	39.3	43.4	1.81	1.97	1.89
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	93.2	93.5	93.3	41.5	42.7	42.1	1.85	1.80	1.82
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	91.4	91.8	91.6	39.8	41.0	40.4	1.81	1.77	1.79
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	94.1	93.5	93.8	41.5	43.1	42.3	1.85	1.80	1.82
Sole GSC 6 (30cm, F)	68.0	70.7	69.3	31.9	29.3	30.6	1.76	1.82	1.79
Sole GSC 7 (30cm, F)	73.2	78.1	75.6	39.3	34.4	36.9	1.89	2.01	1.95
Sole Hyola PAC 401 (30cm, F)	74.6	71.1	72.9	29.6	33.1	31.3	1.80	1.71	1.76
Sole GP (60cm, R)	107.7	146.6	127.2	75.4	53.0	64.2	1.97	2.06	2.01
Sole GP (30cm, F)	125.2	159.4	142.3	84.0	65.4	74.7	2.09	2.11	2.10

NS= Non-significant, MSP – Oil seed rape (2017- ₹ 3700 q⁻¹, 2018- ₹ 4000 q⁻¹), Garden pea (2017- ₹ 830 q⁻¹, 2018- ₹ 850 q⁻¹)

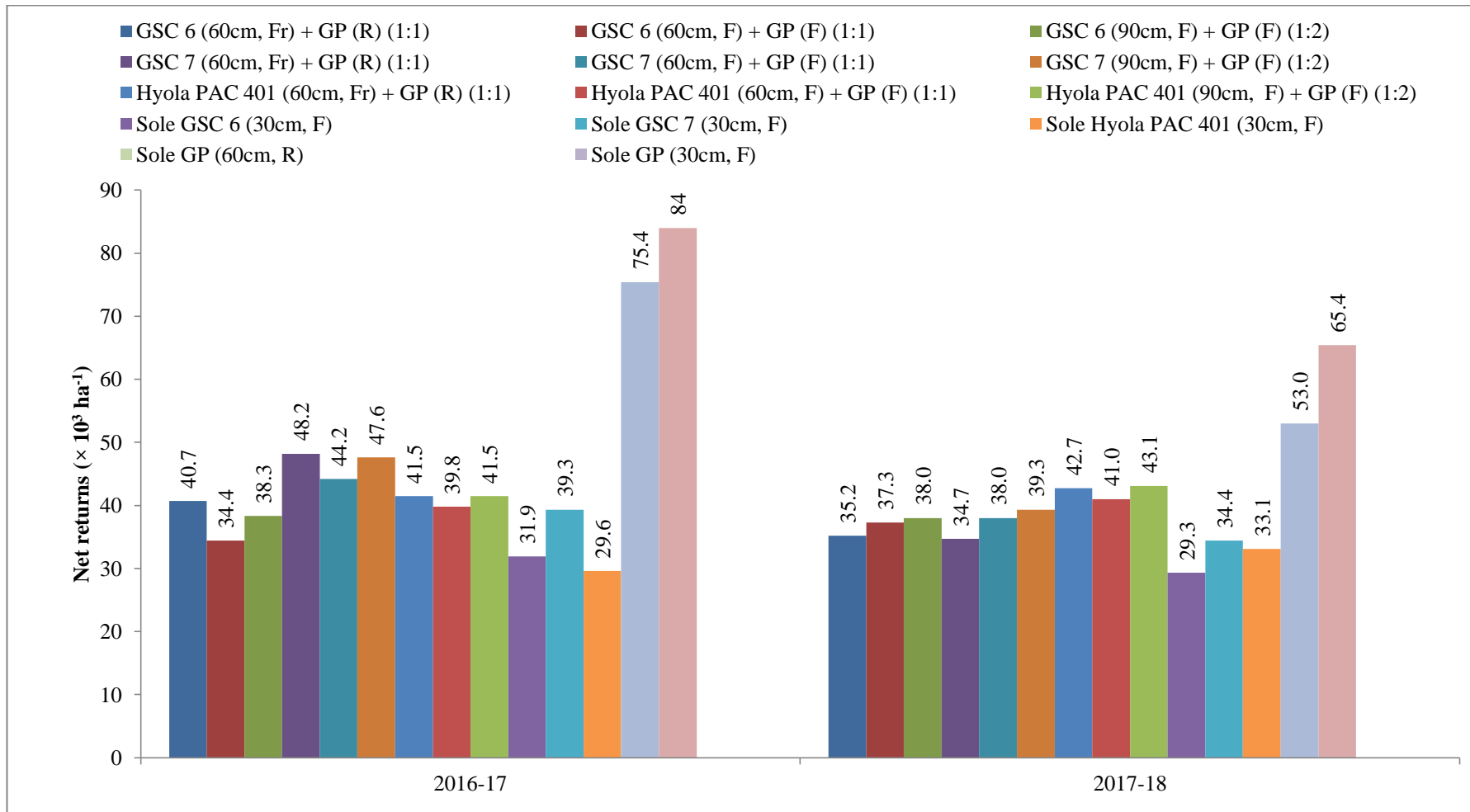


Fig. 6: Net returns of different oilseed rape based intercropping systems during 2016-17 and 2017-18

resulted in highest net returns as compared to their sole counterparts (Choudhury and Jana 2015). There was increase in net return to the tune of ₹ 5,300 to ₹ 7,600, ₹ 4,200 to ₹ 6,500 and ₹ 9,100 to ₹ 11,000 in GSC 6, GSC 7 and Hyola PAC 401, respectively in intercropping system as compared to their respective sole crop treatments. The mean of data of both the cropping seasons indicated that flat sown sole garden pea recorded higher net returns. Among the different intercropping treatments net returns were similar in different intercropping systems.

4.7.5 Benefit: Cost ratio (B: C)

The data recorded on B: C is given in table 21. The data envisaged that flat sown sole garden pea recorded higher B: C during both the cropping seasons of 2016-17 and 2017-18. Similar trend was shown by mean of both years. Among the different intercropping treatments maximum B: C was obtained in flat sown GSC 7 + garden pea in 1:2 row ratio (1.89) and minimum was obtained in flat sown GSC 6 + garden pea in 1:1 (1.74).

4.8 Competitive indices

4.8.1 Land Equivalent Ratio (LER)

LER values of different intercropping system are presented in table 22. Higher value of LER in an intercropping system indicates higher yield advantage over other intercropping treatments. Among the different intercropping systems there was no significant difference in LER during both the cropping seasons of 2016-17 and 2017-18. LER values of different intercropping system are more than one, thus indicating that there is yield advantage from all the intercropping systems. However, flat sown Hyola PAC 401+ garden pea in 1:2 row ratio recorded higher value of LER as compared to other treatments during both the cropping seasons.

4.8.2 Area Time Equivalent Ratio (ATER)

ATER provides a realistic comparison of yield advantage of intercropping over that of sole cropping because it considers variation in time taken by component crops in different intercropping systems. Values of different intercropping systems (Table 22) indicated that there was no significant difference among intercropping systems during both the cropping seasons of 2016-17 and 2017-18.

4.8.3 Aggressivity (A)

The data on aggressivity (A) value are presented in table 22. The greater the numerical value, the higher is the difference in competitive abilities. Flat sown GSC 6 + garden pea (1:2), GSC 7 + garden pea (1:2) and Hyola PAC 401 + garden pea (1:2) recorded significantly higher values of aggressivity than all the intercropping systems during both the

Table 22: Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER) and Aggressivity as influenced by different intercropping systems

Treatment	LER		ATER		Aggressivity 2016-17		Aggressivity 2017-18	
	2016-17	2017-18	2016-17	2017-18	Oilseed rape	Garden pea	Oilseed rape	Garden pea
GSC 6 (60cm, Fr) + GP (R) (1:1)	1.13	1.12	1.10	1.09	1.61	-1.61	1.62	-1.62
GSC 6 (60cm, F) + GP (F) (1:1)	1.16	1.04	1.12	1.01	1.58	-1.58	1.43	-1.43
GSC 6 (90cm, F) + GP (F) (1:2)	1.13	1.05	1.09	1.01	2.68	-2.68	2.39	-2.39
GSC 7 (60cm, Fr) + GP (R) (1:1)	1.07	1.11	1.05	1.08	1.55	-1.55	1.56	-1.56
GSC 7 (60cm, F) + GP (F) (1:1)	1.11	1.07	1.09	1.05	1.72	-1.72	1.58	-1.58
GSC 7 (90cm, F) + GP (F) (1:2)	1.11	1.07	1.08	1.04	2.74	-2.74	2.47	-2.47
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	1.18	1.18	1.14	1.15	1.62	-1.62	1.69	-1.69
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	1.15	1.13	1.11	1.10	1.59	-1.59	1.62	-1.62
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	1.15	1.14	1.12	1.11	2.74	-2.74	2.67	-2.67
LSD (p=0.05)	NS	NS	NS	NS	0.37	0.37	0.65	0.65

NS= Non-significant

Table 23: Competition ratio and Monetary Advantage Index (MAI) of oilseed rape based intercropping system

Treatment	Competitive ratio 2016-17		Competitive ratio 2017-18		MAI (₹ ha ⁻¹)	
	Oilseed rape	Garden pea	Oilseed rape	Garden pea	2016-17	2017-18
GSC 6 (60cm, Fr) + GP (R) (1:1)	3.16	0.34	3.11	0.33	43255.9	43802.1
GSC 6 (60cm, F) + GP (F) (1:1)	2.84	0.40	2.75	0.39	52859.7	30511.8
GSC 6 (90cm, F) + GP (F) (1:2)	4.13	0.26	3.44	0.32	33330.8	21435.0
GSC 7 (60cm, Fr) + GP (R) (1:1)	3.21	0.32	2.72	0.35	34376.2	48347.4
GSC 7 (60cm, F) + GP (F) (1:1)	3.97	0.25	3.31	0.31	37132.4	37347.8
GSC 7 (90cm, F) + GP (F) (1:2)	4.83	0.21	3.51	0.29	28190.2	28305.2
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	2.94	0.37	3.02	0.34	58055.7	56565.7
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	3.00	0.38	3.01	0.33	53898.9	46631.1
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	4.07	0.25	3.74	0.30	41190.6	39672.3
LSD (p=0.05)	1.08	NS	0.45	NS	NS	NS

NS= Non-significant

cropping seasons. The results of aggressivity showed that oilseed rape was the dominant species with positive values in intercropping system over the garden pea which had negative values of aggressivity in both the cropping seasons.

4.8.4 Competitive Ratio (CR)

Competitive ratio (CR), is another way to know the degree with which one crop competes with its component crop. The data regarding CR values are presented in table 23. The data indicated that CR of oilseed rape was significantly higher in flat sown GSC 7 + garden pea (1:2) during 2016-17 and it was statistically at par with flat sown GSC 6 + garden pea (1:2), flat sown Hyola PAC 401 + garden pea (1:2) and flat sown GSC 7 + garden pea (1:1). Whereas, during 2017-18, it was significantly higher in flat sown Hyola PAC 401 + garden pea in 1:2 row ratio and statistically at par with flat sown GSC 7 + garden pea (1:2), flat sown GSC 6 + garden pea (1:2) and flat sown GSC 7 + garden pea (1:1). There was no significant difference in the CR of garden peas in intercropping systems. Higher CR values of oilseed rape indicated that it was more competitive and dominant species in intercropping.

4.8.5 Monetary Advantage Index (MAI)

The data recorded on MAI are given in table 23. The data revealed that, there was no significant difference in MAI of different intercropping systems. However, Hyola PAC 401 + garden pea (1:1) intercropping system recorded comparatively higher MAI as compared to other intercropping systems.

4.10 Soil analysis

4.10.1 Available N

The available N status of surface soil after harvest of component crops was increased from its initial status in case of intercropping system (Table 24). The available N status of soil showed that ridge sown sole garden pea recorded highest available N which was statistically at par with flat sown sole garden pea. However, among the intercropping systems different oilseed rape cultivars in 1:2 row ratio recorded available N, which was statistically better than their respective 1:1 row ratio based intercropping systems.

4.10.2 Available P

The data pertaining to available P, presented in table 24 revealed that available P of soil after harvest of oilseed rape and garden pea was not significantly influenced by different intercropping systems.

4.10.3 Available K

The data recorded for available K (Table 24) indicated that there was no significant difference among intercropping systems with regard to available K. However, the available K of surface soil after harvest of crops increased from its initial potassium status in intercropping treatments.

Table 24: Nitrogen, phosphorus and potassium status of soil at harvest as influenced by different intercropping systems

Treatment	Available N (kg ha⁻¹)	Available P (kg ha⁻¹)	Available K (kg ha⁻¹)
GSC 6 (60cm, Fr) + GP (R) (1:1)	177.4	21.8	158.0
GSC 6 (60cm, F) + GP (F) (1:1)	171.7	21.9	158.2
GSC 6 (90cm, F) + GP (F) (1:2)	186.6	20.8	157.7
GSC 7 (60cm, Fr) + GP (R) (1:1)	170.7	22.9	157.7
GSC 7 (60cm, F) + GP (F) (1:1)	169.4	22.7	157.7
GSC 7 (90cm, F) + GP (F) (1:2)	181.3	21.7	156.3
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	177.4	23.5	161.5
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	175.3	23.9	159.0
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	187.8	22.8	158.4
Sole GSC 6 (30cm, F)	155.7	22.5	154.3
Sole GSC 7 (30cm, F)	159.4	22.3	152.5
Sole Hyola PAC 401 (30cm, F)	154.3	23.5	155.7
Sole GP (60cm, R)	195.7	22.3	163.5
Sole GP (30cm, F)	193.4	23.2	161.4
LSD (p=0.05)	5.2	NS	NS

NS= Non-significant

4.9 Plant analysis

4.9.1 Seed and stover nitrogen (N) content and uptake

Data pertaining to the N content and uptake by seed and stover of oilseed rape are presented in table 25. Differences in seed and stover nitrogen content by oilseed rape were recorded to be statistically at par during both the cropping seasons. N uptake by seed of oilseed rape was also non-significant during both the cropping seasons. During 2016-17, N uptake by oilseed rape stover was recorded to be significantly higher in flat sown GSC 7 + garden pea (1:2) which was statistically at par with GSC 7 + garden pea (1:1) sown in both flat and furrows and Hyola PAC 401 + garden pea (1:1) in furrows and significantly higher than all other treatments. Similar trend was followed during second year. Total N uptake was recorded to be significantly highest in flat sown GSC 7 + garden pea (1:1) during 2016-17 and furrow sown GSC 7 + ridge sown garden pea (1:1) during 2017-18.

4.9.2 Seed and stover phosphorus (P) content and uptake

The data on P content and uptake by seed and stover of oilseed rape are presented in table 26. P content and uptake by seed as well as stover of oilseed rape indicated no any significant difference during the cropping seasons of 2016-17 and 2017-18. Whereas, there was no significant difference in total P uptake during both the cropping seasons.

4.9.3 Seed and stover potassium (K) content and uptake

Data regarding oilseed rape K content and uptake by seed and stover of oilseed rape are presented in table 27. The differences in K content of seed as well as stover of oilseed rape were statistically at par during both the cropping seasons. K uptake by seed of oilseed rape also showed no significant difference during both the cropping seasons. However, there was significant difference in K uptake by oilseed rape stover and total K uptake. Flat sown GSC 7 + garden pea in 1:2 row ratio recorded significantly higher stover K uptake during both the cropping seasons, except during 2017-18, where it was statistically at par with sole GSC 7. Total K uptake was also recorded to be significantly higher in flat sown GSC 7 + garden pea in 1:2 row ratio during both the cropping seasons.

Table 25: Nitrogen (N) content and uptake in seed and stover of oilseed rape as influenced by intercropping systems

Treatments	N content (%)				N uptake (kg ha ⁻¹)				Total N uptake (kg ha ⁻¹)	
	2016-17		2017-18		2016-17		2017-18		2016-17	2017-18
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover		
GSC 6 (60cm, Fr) + GP (R) (1:1)	2.54	0.58	2.53	0.57	41.4	32.64	42.2	32.15	74.0	74.4
GSC 6 (60cm, F) + GP (F) (1:1)	2.53	0.57	2.52	0.57	41.7	33.21	38.0	32.94	74.9	70.9
GSC 6 (90cm, F) + GP (F) (1:2)	2.56	0.58	2.54	0.58	42.8	32.83	38.2	32.39	75.6	70.6
GSC 7 (60cm, Fr) + GP (R) (1:1)	2.62	0.61	2.59	0.60	43.5	42.40	47.4	40.68	85.9	88.1
GSC 7 (60cm, F) + GP (F) (1:1)	2.60	0.60	2.57	0.60	47.5	42.23	46.8	39.20	89.7	86.0
GSC 7 (90cm, F) + GP (F) (1:2)	2.63	0.61	2.62	0.61	44.9	44.54	45.6	40.61	89.4	86.2
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	2.54	0.58	2.52	0.57	46.6	42.18	44.5	40.66	88.8	85.2
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	2.52	0.57	2.46	0.54	46.3	41.23	42.1	38.04	87.5	80.1
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	2.56	0.58	2.54	0.58	41.2	38.63	42.0	37.57	79.8	79.6
Sole GSC 6 (30cm, F)	2.26	0.46	2.25	0.47	39.1	31.55	40.3	31.26	70.7	71.6
Sole GSC 7 (30cm, F)	2.3	0.48	2.29	0.47	41.7	37.40	45.2	37.91	79.1	83.1
Sole Hyola PAC 401 (30cm, F)	2.28	0.47	2.27	0.47	42.8	37.39	40.8	36.82	80.2	77.6
LSD (p=0.05)	NS	NS	NS	NS	NS	2.41	NS	2.20	1.31	1.47

NS=Non-significant

Table 26: Phosphorus (P) content and in seeds and stover of oilseed rape as influenced by intercropping systems

Treatments	P content (%)				P uptake (kg ha ⁻¹)				Total P uptake (kg ha ⁻¹)	
	2016-17		2017-18		2016-17		2017-18		2016-17	2017-18
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover		
GSC 6 (60cm, Fr) + GP (R) (1:1)	0.36	0.11	0.35	0.09	6.1	6.2	5.2	5.1	12.3	10.3
GSC 6 (60cm, F) + GP (F) (1:1)	0.36	0.08	0.36	0.08	6.0	4.6	4.8	4.6	10.6	9.4
GSC 6 (90cm, F) + GP (F) (1:2)	0.37	0.12	0.36	0.11	6.2	6.7	4.8	6.1	12.9	10.9
GSC 7 (60cm, Fr) + GP (R) (1:1)	0.38	0.12	0.35	0.12	6.5	8.4	5.7	8.1	14.9	13.8
GSC 7 (60cm, F) + GP (F) (1:1)	0.36	0.08	0.31	0.07	6.7	5.6	5.0	4.6	12.3	9.6
GSC 7 (90cm, F) + GP (F) (1:2)	0.38	0.13	0.36	0.12	6.9	9.5	5.6	8.0	16.4	13.6
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	0.39	0.11	0.37	0.10	7.4	8.1	5.8	7.2	15.5	13.0
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	0.37	0.09	0.35	0.08	6.9	6.5	5.3	5.6	13.4	10.9
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	0.41	0.07	0.39	0.06	7.7	4.6	5.7	3.9	12.3	9.6
Sole GSC 6 (30cm, F)	0.34	0.09	0.32	0.08	6.0	6.1	5.0	5.3	12.1	10.3
Sole GSC 7 (30cm, F)	0.34	0.10	0.33	0.10	6.4	7.8	6.0	8.0	14.2	14.0
Sole Hyola PAC 401 (30cm, F)	0.34	0.10	0.34	0.09	6.5	7.9	5.4	7.0	14.4	12.4
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS=Non-significant

Table 27: Potassium (K) content and uptake in seed and stover of oilseed rape as influenced by intercropping systems

Treatments	K content (%)				K uptake (kg ha ⁻¹)				Total K uptake (kg ha ⁻¹)	
	2016-17		2017-18		2016-17		2017-18		2016-17	2017-18
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover		
GSC 6 (60cm, Fr) + GP (R) (1:1)	0.14	1.89	0.13	1.85	2.2	107.1	1.95	104.0	109.3	106.0
GSC 6 (60cm, F) + GP (F) (1:1)	0.16	1.86	0.15	1.84	2.5	108.0	2.03	106.0	110.5	108.0
GSC 6 (90cm, F) + GP (F) (1:2)	0.18	2.21	0.17	2.18	2.8	124.2	2.3	121.7	127.0	124.0
GSC 7 (60cm, Fr) + GP (R) (1:1)	0.16	1.92	0.15	1.89	2.5	133.9	2.47	127.3	136.4	129.8
GSC 7 (60cm, F) + GP (F) (1:1)	0.14	1.87	0.15	1.85	2.4	131.6	2.45	121.7	134.0	124.2
GSC 7 (90cm, F) + GP (F) (1:2)	0.22	2.27	0.19	2.24	3.7	165.2	2.99	149.6	168.9	152.6
Hyola PAC 401 (60cm, Fr) + GP (R) (1:1)	0.17	1.96	0.15	1.95	3.0	143.5	2.37	139.6	146.5	142.0
Hyola PAC 401 (60cm, F) + GP (F) (1:1)	0.17	2.12	0.16	1.99	2.7	153.9	2.45	139.1	156.6	141.6
Hyola PAC 401 (90cm, F) + GP (F) (1:2)	0.21	2.31	0.19	2.30	3.7	152.8	2.83	149.0	156.5	151.8
Sole GSC 6 (30cm, F)	0.12	1.72	0.10	1.71	1.9	116.9	1.57	114.2	118.8	115.8
Sole GSC 7 (30cm, F)	0.13	1.78	0.12	1.77	2.2	138.7	3.14	142.2	140.9	145.3
Sole Hyola PAC 401 (30cm, F)	0.16	1.77	0.15	1.75	2.9	140.2	2.4	136.5	143.1	138.9
LSD (p=0.05)	NS	NS	NS	NS	NS	9.30	NS	9.70	10.1	9.6

NS=Non-significant

CHAPTER V

SUMMARY

Even though India has achieved remarkable success in increasing the yield of major cereals and has gained potential self sufficiency, India is still facing constraints in meeting the demands for edible oils for ever growing population of the country. Therefore, cultivation of oilseed crops in India assume greater significance to meet the edible oil requirements by its own, which will reduce the import of edible oils. Canola (*Brassica napus* L. and *Brassica campestris* L.) is an important oilseed crop of the world. It is grown under assured irrigation conditions among the different *rabi* oilseed crops. Canola oil is known to promote good health due to its very low saturated fat and high mono unsaturated fatty acid (MUFA).

Due to the ever decreasing per capita availability of land, there is very little chance for horizontal growth of the crop. Thus, production of rapeseed-mustard can be increased by vertical growth of the crop through intercropping with other crops. Intercropping being an advanced agro technique (Naeem *et al* 2013 and Aziz *et al* 2015), aids in improving the agronomic output and economic efficiency of a cropping system than the monoculture through effective use of resources (Khan *et al* 2012). Canola + wheat (1:1) appeared to be highly profitable intercropping pattern (Ali *et al* 2000) and strip intercropping of wheat + canola (4:4) gave higher net returns, LER and B:C ratio over mixed intercrop treatments (Naeem *et al* 2013). *Brassica* based intercropping has assumed vital importance, as it generates more income per unit area under given set of conditions. Intercropping of oilseed rape varieties GSL 1 and GSC 6 at 60 cm spacing with oats fodder in 1: 2 row ratio recorded more economic returns due to higher oilseed rape equivalent yield (Singh and Singh 2014). Wheat + hybrid canola intercropping with 4:2 row ratios proved to be more productive in terms of yield, net income and LER (Khan *et al* 2012). Canola + pea intercropping system improved yield, N uptake and net returns (Malhi 2012).

In India, garden pea (*Pisum sativum* L.) is an important annual vegetable crop. It is mainly grown for tender green pods which are used as a fresh vegetable. In oilseed rape, initial stage of vegetative growth is slow and the growth in reproductive phase is quite rapid, so there is an ample scope for intercropping of any short duration leguminous crop during initial stages. Singh *et al* (2012) recorded that intercropping of maize with peas on raised beds resulted in maximum equivalent yield of maize.

The study entitled “Productivity of oilseed rape (*Brassica napus* L.) and garden pea (*Pisum sativum* L.) intercropping system” had been undertaken at student’s Research Farm, Department of Agronomy, PAU, Ludhiana, during *rabi* seasons of 2016-17 and 2017-18, to

evaluate the growth and yield of different oilseed rape cultivars intercropped with garden pea and to find out the optimum planting method of oilseed rape and garden pea intercropping system for higher productivity and economic viability. The soil of the experimental field was loamy sand in texture, normal in pH and EC and low in organic carbon. Available N of the soil was low and both available P and K were medium. The experiment was laid out in randomized complete block design and consisted of three cultivars of oilseed rape *viz.*, GSC 6, GSC 7 and Hyola PAC 401 intercropped with garden pea (Punjab 89) in different row proportions. The row to row spacing was 30 cm in case of sole oilseed rape. The replacement series was followed in case of intercropping system. The row spacing of oilseed rape was 60 and 90 cm in 1:1 and 1:2 row patterns, respectively. The plant population of oilseed rape was kept same in the intercropping system. In case of ridge planting method, the ridges were made at 60 cm row spacing and pea was sown on the top of ridges and oilseed rape in furrows. In garden peas, row to row spacing was 30 cm for flat and 60 cm in case of ridge.

The results of the experiment during both the cropping seasons of 2016-17 and 2017-18 showed that differences in plant height of different cultivars of oilseed rape were not significant at 40 DAS, whereas, at 80, 120 DAS and at harvest significantly higher plant height was recorded in GSC 7 + garden pea (1:2). Whereas, at 80 DAS it was statistically at par with flat sown GSC 7 + garden pea (1:1) and flat sown sole GSC 7, during both the seasons. But at 120 DAS and at harvest, the plant height of GSC 7 in different intercropping system was statistically at par with each other but significantly better than all other treatments. Dry matter accumulation by different cultivars of oilseed rape did not show any significant difference at 40 DAS. But DMA by different cultivars differed statistically both in intercropping system as well as in sole crop stand at 80, 120 DAS and at harvest. At 80, 120 DAS and at harvest, maximum DMA was obtained in sole GSC 7 as compared to all other treatments. At 80 DAS this was statistically at par with flat sown GSC 7 + garden pea in 1:2 row ratio but at harvest it was statistically at par with flat sown sole Hyola PAC 401 during both the cropping seasons. The differences in LAI were statistically at par at 40 DAS and at harvest. Whereas, at 80 and 120 DAS, LAI was recorded to be highest in flat sown sole GSC 7 during both the cropping seasons. The interception of PAR at 40 DAS and at harvest did not show significant differences among different treatments. Whereas, at 80 and 120 DAS, flat sown sole GSC 7 recorded significantly higher PAR.

Different phenological stages of oilseed rape *viz.*, days to 50 per cent seedling emergence, flowering, siliquae formation and days to maturity did not show any significant differences. Yield attributes of oilseed rape *viz.*, number of primary and secondary branches,

siliquae per plant, seeds per siliqua and thousand seed weight did not show any significant differences. The differences in seed yield of oilseed rape were statistically at par during both the cropping seasons. Whereas, seed yield was comparatively higher in sole crop stand of different cultivars of oilseed rape. Flat sown sole Hyola PAC 401 yielded significantly higher stover among all the treatments during 2016-17 and it was at par with flat sown sole GSC 7. Whereas, during 2017-18 stover yield was statistically higher in flat sown GSC 7 and at par with flat sown sole Hyola PAC 401. Among intercropping treatments, furrow sown Hyola PAC 401 + ridge sown garden pea in 1:1 row ratio produced significantly higher stover yield during both the cropping seasons. Flat sown sole Hyola PAC 401 and GSC 7 produced statistically at par biological yield to each other but significantly better than all the treatments. Harvest index of different cultivars of oilseed rape was not significantly influenced by different treatments during both the cropping seasons. Significantly higher equivalent yields of oilseed rape cultivars was recorded in different intercropping systems with garden pea as compared to the sole crop stands of different cultivars of oilseed rape. System productivity was recorded to be significantly higher for flat sown sole garden pea. Whereas, significantly higher system productivity was recorded for all the oilseed rape and garden pea based intercropping systems when compared to their sole crop stands during both the cropping seasons. Seed oil content, oil yield, protein content and protein yield was not affected significantly by different intercropping systems.

In case of garden pea, differences in plant height at 40 DAS were appeared to be statistically at par. But flat sown sole garden pea recorded highest plant height at 80 DAS and at harvest and it was statistically at par with ridge sown sole garden pea during both the cropping seasons. Among the intercropping treatments, garden pea intercropped with oilseed rape in 1:2 recorded higher values of plant height when compared to their height in 1:1 row ratios. In garden pea differences in DMA was found to be statistically at par at 40 DAS. Whereas, DMA was recorded to be highest in ridge sown sole garden pea at 80 DAS and at harvest. It was statistically at par with flat sown sole garden pea only, during both the cropping seasons. Ridge sown sole garden pea (60 cm) produced significantly higher numbers of pods per plant during both the growing seasons. There was no significant difference in production of seeds per pod and hundred seed weight by garden pea among all treatments. Flat sown sole pea produced highest green pod yield which was significantly higher than all other treatments during both the years. Among the intercropping treatments, different cultivars of oilseed rape intercropped with garden pea in 1:2 row ratio recorded higher garden pea green pod yield as compared to 1:1 row ratio but the differences were not significant.

Economic analysis of intercropping system revealed that, flat sown sole garden pea recorded higher gross returns among all the treatments due to its higher potential yield during

both the cropping seasons. All the oilseed rape based intercropping systems resulted in higher gross returns when compared to their gross returns in sole crop stand. Similar trend was shown by net returns. The data on B: C revealed that flat sown sole garden pea recorded higher B: C during both the cropping seasons. Among the different intercropping treatments flat sown GSC 7 + garden pea in 1:2 row ratio recorded highest B: C.

There was no significant difference in recording LER during both the cropping seasons. LER values of different intercropping system are more than one, thus indicating that there is yield advantage from all the intercropping systems. However, flat sown Hyola PAC 401 + garden pea in 1:2 row ratio recorded higher value of LER as compared to other treatments during both the cropping seasons. ATER and MAI of different intercropping systems did not show significant differences during both the cropping seasons. The CR of oilseed rape was significantly higher in flat sown GSC 7 + garden pea (1:2) during 2016-17. Whereas, during 2017-18 it was significantly higher in flat sown Hyola PAC 401 + garden pea in 1:2 row ratio. There was no significant difference in the CR of garden peas in intercropping systems. Flat sown GSC 6 + garden pea (1:2), GSC 7 + garden pea (1:2) and Hyola PAC 401 + garden pea (1:2) recorded significantly higher value of aggressivity than all the intercropping system during both the cropping seasons.

N, P and K content of seed as well as stover of oilseed rape were not affected significantly by the intercropping systems. However, N, P and K uptake by seed and P uptake by stover of oilseed rape also did not show any significant difference. N uptake by stover was recorded to be significantly higher in flat sown GSC 7 + garden pea in 1:2 during 2016-17 and furrow sown GSC 7 + ridge sown garden pea in 1:1 during 2017-18. But K uptake by stover of oilseed rape was significantly higher in GSC 7 + garden pea in 1:2 row ratio during both the years.

Conclusions

- The growth and yield of GSC 6, GSC 7 and Hyola PAC 401 was not affected significantly when intercropped with garden pea. On an average, garden pea gave 20.3 to 28.9 q ha⁻¹ green pod yield under different intercropping treatments.
- Intercropping of oilseed rape cultivars with garden pea in either 1:1 or 1:2 row ratio, irrespective of the planting methods, produced higher oilseed rape equivalent yield, gross returns and net returns than sole crop of oilseed rape.

From the overall appraisal of the study, it can be concluded that as compared to sole oilseed rape crop, intercropping with garden pea makes oilseed rape intercropping system more remunerative because of increase in the net returns to the tune of ₹4,200 to ₹11,000 ha⁻¹.

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APPENDIX I

**Weekly meteorological data recorded during *rabi* 2016-17 at Meteorological
Observatory, PAU Ludhiana**

Standard Meteorological Week (SMW)	Temperature (°C)			Relative humidity (%)			Total rainfall (mm)	Total evaporation (mm)	Sunshine (hrs)
	No.	Max.	Min.	Mean	M	E			
45	27.6	14.7	21.2	78.0	35.0	56.5	0.7	19.0	3.4
46	26.6	10.7	18.7	91.0	31.0	60.8	0.0	16.5	7.7
47	27.6	11.7	19.7	86.0	28.0	57.1	0.0	18.3	7.6
48	26.3	9.2	17.8	90.0	37.0	63.3	0.0	7.1	5.4
49	23.5	10.4	16.9	95.0	57.0	76.1	0.0	7.4	2.6
50	19.8	8.7	14.2	97.0	58.0	77.5	0.0	9.9	2.7
51	22.5	6.9	14.7	92.0	43.0	67.5	0.0	10.2	6.3
52	21.3	8.0	14.7	95.0	47.0	71.0	0.0	9.7	5.7
1	19.9	9.4	14.6	95.0	60.0	77.4	0.6	9.8	2.6
2	16.6	3.5	10.0	93.0	41.0	67.4	0.2	8.6	6.7
3	16.4	6.5	11.5	95.4	64.0	79.7	0.0	9.5	3.8
4	19.1	10.7	14.9	93.6	69.3	81.4	5.8	8.0	3.5
5	20.0	9.3	14.6	93.4	65.9	79.6	0.7	8.0	3.6
6	20.9	6.8	13.9	94.1	47.4	70.8	0.0	12.0	7.4
7	25.1	11.2	18.1	88.4	45.4	66.9	0.0	17.0	7.4
8	24.4	9.4	16.9	89.6	38.4	64.0	0.0	19.4	9.5
9	25.5	9.5	17.5	91.0	34.0	62.5	0.0	20.9	9.5
10	20.2	10.3	15.2	85.0	47.9	66.4	5.8	21.3	7.1
11	24.2	9.7	16.9	86.9	41.7	64.3	0.0	24.9	8.3
12	27.4	12.6	20.0	82.0	36.0	59.0	0.0	20.0	9.8
13	35.5	18.9	27.2	83.1	29.0	56.1	0.0	27.0	10.9
14	20.4	9.2	14.8	91.0	54.6	72.8	0.7	40.5	3.7

APPENDIX II

Weekly meteorological data recorded during *rabi* 2017-18 at Meteorological Observatory, PAU Ludhiana

Standard Meteorological Week (SMW)	Temperature (°C)			Relative humidity (%)			Total rainfall (mm)	Total evaporation (mm)	Sunshine (hrs)
	No.	Max.	Min.	Mean	M	E			
45	25.7	14.0	19.8	97.0	57.0	77.0	0.0	7.6	2.1
46	22.1	12.2	17.2	89.3	57.7	74.0	1.0	8.2	2.0
47	24.2	7.4	15.8	94.0	31.0	63.0	0.0	16.6	8.0
48	25.2	7.8	16.5	94.4	32.6	64.0	0.0	14.0	7.0
49	22.9	7.2	15.1	86.0	27.0	57.0	0.0	14.0	6.7
50	16.4	9.1	12.7	90.4	74.0	82.0	3.4	9.2	3.6
51	21.0	8.1	15.6	94.8	34.0	64.0	0.0	10.0	7.0
52	23.0	7.1	14.3	88.4	54.3	72.0	0.0	9.1	3.4
1	15.0	5.4	10.6	96.0	66.0	81.0	0.0	6.2	2.6
2	20.1	5.3	13.3	94.0	43.0	69.0	0.0	11.6	7.6
3	22.0	6.1	14.1	92.0	40.0	66.0	0.0	14.4	7.7
4	15.0	7.6	11.5	93.0	76.0	85.0	18.0	9.6	3.6
5	21.0	7.6	14.4	91.0	46.0	69.0	0.0	13.6	8.1
6	21.0	5.6	13.4	89.0	38.0	63.0	2.0	15.0	8.0
7	21.0	9.3	15.2	89.0	38.0	63.0	2.0	15.8	7.4
8	25.0	11.7	18.6	88.0	48.0	68.0	3.0	17.4	7.5
9	25.0	13.1	19.4	89.0	51.0	70.0	0.0	17.9	6.5
10	27.0	12.2	19.7	8.8	42.0	65.0	0.0	24.4	10.4
11	29.9	14.1	22.0	85.0	30.0	58.0	0.0	29.8	10.0
12	29.2	14.2	21.7	86.0	44.0	65.0	0.0	27.8	7.8
13	33.1	16.5	24.8	74.0	29.0	52.0	0.0	38.6	10.1
14	34.8	20.3	27.5	69.0	33.0	51.0	0.0	42.2	5.9

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