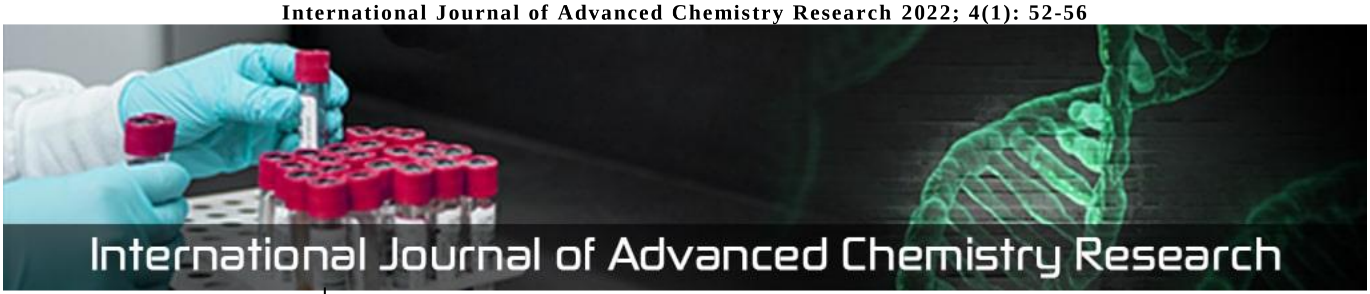

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Study on mint (*Mentha arvensis*) Intercropping with maize (*Zea mays*) and Wheat (*Triticum aestivum*)

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Abstract
The present work was undertaken to Study the Mint (*Mentha arvensis*) intercropping with Maize (*Zea mays*) and Wheat (*Triticum aestivum*). The field experiment was conducted at Khalsa College Amritsar. Eight treatments were studied *viz.* T_1, Mint sole T_2, Mentha sown on beds as relay in bed planted wheat, T_3, Mentha sown in furrow as relay in beds planted wheat, T_4, Mentha on beds after the harvesting of wheat, T_5, Mentha in furrow after the harvesting of wheat, T_6, Maize plus Mint on beds, T_7, Maize plus Mint in furrow, T_8, Maize sole. The result revealed that in the treatment T_1 sole mint shows higher herbage yield (205.4 q/ha) and oil yield (132.4 kg/ha) as compare to intercropping with wheat and maize in treatments T_2, T_3, T_6, T_7 respectively. Sole mint also produce higher growth and yield parameter than crop sown in nursery transplanted in the month of April in treatments T4 and T5. However Land equivalent ratio (LER), Area time equivalent ratio (ATER), Monetary advantage index (MAI) were higher in intercropping. Descending order of herbage yield was from T_1 (205.4 q/ha)> T_3 (192.5 q/ha)> T_2 (177.5q/ha) > T_4 (165.2 q/ha) > T_5 (145.2 q/ha) > T_7 (140 q/ha) > T_6 (124.2 q/ha) respectively.

Keywords: Intercropping, wheat mint relay cropping, land equivalent ratio, japanese mint, essential oil, menthol, maize, sequential cropping

Introduction
Mints are perennial herbaceous plants, belonging to the family *Lamiaceae*. The various species of mints which are commercially cultivated in different parts of the world are: Japanese mint or corn mint or field mint (*Mentha arvensis*), Peppermint (*Mentha piperita*), Spear mint or garden mint or lamb mint (*Mentha spicata*) and Bergamot mint or orange mint (*Mentha citrate*).

The essential oil, menthol crystals, dementholated oil and minor monoterpenes fractionated from the dementholated oil find uses in the food, flavour, pharmaceutical, cosmetic and agrichemical industries (Kumar *et al.* 2002). It is a potential source of natural menthol and other ingredients like mint terpenes, menthone isomenthone, menthyl acetate etc (Pal *et al.* 2020) [3]. Mentha plays a very significant role in the agricultural economy. The crop is economically significant not only for its contribution to the livelihood of thousand of farmers but also for its highly diversified industrial use in confectionary, cosmetic and pharmaceutical sectors.

Wheat has a distinct place among the food grain crops and globally it is the leading source of protein in human food, having a protein content of about 13 percent, which is relatively high compared to other cereals. In India it is the second important staple food crop, providing almost half of all calories in the region of North Africa and West and Central Asia (Tiwari *et al.*. 2019) [4]. The products of flour milling i.e. bran is used as animal feed. Wheat straw is used as an excellent feed for livestock in developing countries whereas in developed countries it is used for bedding on farms and paper manufacturing. The common wheat is good for ´chapatti´ making and bakery products.

Maize (*Zea mays*) belonging to the family *Poaceae*. Maize is the most important grain crop in South Africa and is produced throughout the country under diverse environments. It occupies the third position next to rice and wheat in area and production. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc.

In nearly all developing countries the traditional agricultural systems are based on the growing of crops in mixtures, a system most commonly referred to as intercropping or mixed cropping. Intercropping is a wide spread agronomic practice in the tropics because it reduces the losses caused by pests, diseases and weeds, as well as also guarantee better yield (Lulie *et al.* 2014) [5]. In addition to resource use efficiency intercropping also plays a significant role in weed suppression due to spatial competition between the component crops (Wasaya *et al.* 2013) [7].

Intercropping of medicinal crops in the existing cropping systems would be more appropriate to boost up farmers income and fulfil the nations domestic and export demand. Medicinal and aromatic plants play important roles in human health services worldwide. Many people in both developing and developed countries are turning to herbal medicine. The intercropping of aromatic and cereal crops are done to fulfil the demand of people and also to get more benefit for the supply of medicinal and cereal crops together.

Documented information on intercropping of wheat and maize varieties with mint is scanty (Lulie *et al.* 2014) [5]. Also information on the profitability of cereal and aromatic cropping system is lacking. So there is a need for developing technology suitable for wheat, maize, mint intercropping.

Materials and methods

Site description: Amritsar is situated at 31.38 degree North latitude, 74.52 degree East longitudes and at an altitude of 236 meters above mean sea level. This track is characterized by semi-humid climate, where both winters and summers are extreme. The summer maximum temperature of about 35-40° C is not uncommon during summer, while freezing temperature accompanied by frost occurrence may be witnessed in the month of December and January and during winter, the temperature ranges from 22°C to about -2°C. The monsoon generally starts in the month of July. The soil of the experimental field was sandy loam in texture having saline PH (8.4) and electric conductivity, low in organic carbon (0.48%), low in available nitrogen (177 kg/ha), medium in available phosphorus (18 kg/ha) and high in available potassium (360 kg/ha).

Experimental design and treatments

The present field trial on "Study on Mint (Menthe arvensis) intercropping with Maize (*Zea mays*) and Wheat (*Triticum aestivum*)" would be conducted at the Students Research Farm Khalsa College, Amritsar during Rabi season 2020-2021. A total of 8 treatments were tried in a Randomized Block Design with 8 treatments.

Mentha sole	T_1
Mentha sown on beds as relay crop in bed planted wheat	T_2
Mentha sown in furrow as relay crop in bed planted wheat	T_3
Mentha on beds after harvesting of bed planted wheat	T_4
Mentha in furrow after harvesting of bed planted wheat	T_5
Maize plus mint on beds	T_6
Mint plus maize in furrow	T_7
Sole maize	T_8

Experimental observations

Growth attributes**:** Plant height**,** Leaf area index**,** Dry matter accumulation**.** Yield attributes: Effective tillers**,** Spikelets per spike**,** Number of grains per ear**,** 1000 grain weight**,** Grain yield**,** Straw yield**,** Harvest index for wheat crop.

Phenological stages. Growth attributes: Plant height, Leaf area index, Dry matter accumulation. Yield attributes: Thousand test weight, Number of cobes, number of rows per cob, number of grains per cob, Grain yield, stover yield, harvest index for maize crop.

Growth attributes: Plant height, Leaf area index, number of leaves, fresh weight. Yield attributes: Oil yield, Herbage yield, oil content for the mint crop.

Oil Yield and Oil Content

Oil was extracted from leaves of the mint crop. The crushed material was carefully transferred to Soxhlet´s extractor, nearly two-third of the flask with petroleum ether (60-80°C). The whole system was fitted on an electric hot plate. After distillation for 3 hours, the distillates were collected. Final calculation was done by using the following formula:

Percentage of oil = Constant weight of oil × 100 / Weight of herbage

$$\text{Percentage of oil} = \frac{\text{Constant weight of oil}}{\text{Weight of herbage}} \times 100$$

Agronomic advantages

Mint equivalent yield (MEY)

The yield of the individual crop was converted into equivalent yield (q ha^{-1}) on the basis of the market price of the crop. It was calculated by the formula;

$$\text{MEY} = \frac{\text{herbage yield of mint+ grain yield of wheat/maize} \times \text{price of wheat/maize}}{\text{Price of mint}}$$

Land equivalent ratio (LER)

It is the relative land area under sole crops that are required to produce the yields achieved in intercropping. It is usually assumed that the level of management must be the same for intercropping as for sole cropping. It was calculated as follows:

LER = LER (wheat) + LER (mint)

LER = LER (maize) + LER (mint)

Where,

$$\text{LER (Wheat)} = \frac{\text{Intercropped yield of wheat}}{\text{Sole crop yield of wheat}}$$

$$\text{LER (Maize)} = \frac{\text{Intercropped yield of maize}}{\text{Sole crop yield of maize}}$$

$$\text{LER (Mint)} = \frac{\text{Intercropped yield of mint}}{\text{Sole crop yield of mint}}$$

Competitive indices

Area time equivalent ratio (ATER)

ATER takes into account the duration of crops and permits an evaluation of crops on yield per day basis. It is a modification of LER and expressed as below:

$$\text{ATER} = \frac{\{(La \text{ x } Da) + (Lb \times Db)\}}{T}$$

Where La and Lb are the relative yied or partial LER of component crops ‘a’ and ‘b’; Da and Db is the duration of component crops and T is the total duration of intercropping system.

Monetary Advantage Index (MAI)

MAI provides us the clear information on the economic advantage of the intercropping system (Gosh 2004). For the reason, the monetary advantage index (MAI) was calculated as:

MAI (Rs./ha) = commercial value of combined crops × LER -1 / LER

Result and discussion

Plant height

Mint

The data showed that with increase in the age of the crop plants height also increased. At 30 DAS, the plant height was not significantly influenced by the effect of intercropping. Further, it was observed that plant height significantly affected at 60, 90, 120 DAS and at the time of harvest. This Table indicated that T_1 that is mint sole shows the maximum plant height which was significantly differ to all the other treatments this is due to the proper plant population of the crop was present and there is no effect of intercropping. Treatment T_2 and T_3 shows that upto 60 DAS the plant height was low this is because there is intercropping of wheat and mint crop, the proper availability of sunlight and spacing was not given to the mentha crop after the harvesting of wheat at 90 DAS the plant height of mint was increased at faster rate due to proper environmental conditions. In the treatment T_4 and T_5 shows that there is increase in plant height upto 60 DAS because the mint crop was grown in nursery after the transplanting of mint crop in the field the plant height was decreased due to the transplanting shock. In the maize plus mint intercropping in T_6 and T_7 upto 60 DAS the mint plant height was increased but abruptly decreased after 60 DAS due to the maize height was increased and there is no proper availability of nutrients to mint crop. It was found that plant height obtained from treatment T_1 was 17%, 5.9%, 23.2%, 31.8%, 51.3%, 41.46% greater than treatments T_2, T_3, T_4, T_5, T_6, T_7 respectively.

Table 1: Effect of intercropping on periodic plant height of mint (cm)

Treatments	Plant height				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1: Mentha sole	5.2	19.9	42.7	63.7	84.4
T_2: Mentha sown on beds as relay crop in bed planted wheat	4.1	12.1	33.1	49.4	69.5
T_3: Mentha sown in furrow as relay crop in bed planted wheat	4.2	12.4	38.7	54.7	79.4
T_4: Mentha on beds after harvesting of bed planted wheat	5.0	18.9	30.7	43.4	64.8
T_5: Mentha in furrow after harvesting of bed planted wheat	4.9	18.0	28.9	39.1	57.5
T_6: Maize plus mint on beds	4.6	15.1	22.1	31.4	49.1
T_7: Mint plus maize in furrow	4.8	15.7	26.7	37.9	54.4
T_8: Sole maize	-	-	-		-
CD(0.05)	NS	2.04	2.84	3.32	5.06

Wheat

The result revealed that there was non significant difference observed between all the treatments (T_2, T_3, T_4, and T_5) at all observational periods. Numerically, plant height was higher with T_4 treatment over T_2, T_3 and T_5 treatments at 30, 60, 90, 120 DAS and at harvest stage of crop. Whereas the lowest value of plant height was observed in T_3 treatment at all intervals. Further, it was observed that at 30, 60, 90, 120 DAS and at harvest, the trend of plant height was as $T_4 > T_5 > T_2 > T_3$ this is due to sole bed planting wheat showed higher result due to the reduction of competition in bed planting method which helps the plant for availability of resources in better way.

Table 2: Effect of intercropping on periodic plant height (cm) of wheat

Treatments	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1: Mentha sole	-	-	-	-	-
T_2: Mentha sown on beds as relay crop in bed planted wheat	6.9	19.02	57.91	75.96	99.91
T_3: Mentha sown in furrow as relay crop in bed planted wheat	6.7	18.97	57.45	75.24	99.09
T_4: Mentha on beds after harvesting of bed planted wheat	7.3	19.63	58.62	76.61	101.43
T_5: Mentha in furrow after harvesting of bed planted wheat	7.0	19.12	58.37	76.05	100.04
T_6: Maize plus mint on beds	-	-	-	-	-
T_7: Mint plus maize in furrow	-	-	-	-	-
T_8: Sole maize	-	-	-	-	-
CD (0.05)	NS	NS	NS	NS	NS

Maize

The periodic mean values of plant height have been presented in Table 3. Data indicated that in general, the plant height increases throughout the observation periods. During the initial stage of crop growth, the increment in plant height was slow upto 90 DAS, their after plant height increased at a fastest rate to the harvest. . In the intercropping of maize plus mint in the treatment T_6 shows the higher results as compare to the other treatments. The sole maize and intercropping of maize plus mint donot show the significant difference. This possibly due to less competition from spearmint and also better availability of water and nutrients.

Table 3: Effect of intercropping on periodic plant height of maize (cm)

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1: Mentha sole	-	-	-	-
T_2: Mentha sown on beds as relay crop in bed planted wheat	-	-	-	-
T_3: Mentha sown in furrow as relay crop in bed planted wheat	-	-	-	-
T_4: Mentha on beds after harvesting of bed planted wheat	-	-	-	-
T_5: Mentha in furrow after harvesting of bed planted wheat	-	-	-	-
T_6: Maize plus mint on beds	15.95	33.80	78.79	108.73
T_7: Mint plus maize in furrow	15.75	32.80	78.29	108.57
T_8: Sole maize	14.55	30.70	77.78	100.24
CD (0.05)	NS	NS	NS	NS

Yield

Table 4: Effect of intercropping on herbage yield, oil yield and oil content of mint, grain yield of wheat, grain yield of maize.

Treatments	Herbage yield (q/ha)	Oil yield (kg/ha)	Oil content %	Grain yield of wheat	Grain yield of maize
T_1: Mentha sole	205.4	132.4	0.68	-	-
T_2: Mentha sown on beds as relay crop in bed planted wheat	177.6	115.5	0.66	44.8	-
T_3: Mentha sown in furrow as relay crop in bed planted wheat	192.5	125.1	0.67	43.76	-
T_4: Mentha on beds after harvesting of bed planted wheat	165.75	108.1	0.65	45.68	-
T_5: Mentha in furrow after harvesting of bed planted wheat	145.5	99.73	0.64	44.91	-
T_6: Maize plus mint on beds	124.2	83.5	0.61	-	64.81
T_7: Mint plus maize in furrow	140.1	93.0	0.60	-	63.45
T_8: Sole maize	-	-		-	60.58
CD (0.05)	15.04	8.49	NS	NS	NS

Herbage yield

This Table indicated that mint sole that is T_1 shows the significant difference with all other treatment this is because the plant population in this treatment were higher as compare to the other treatments. Treatments T_2 and T_3 are significantly vary to each other because in treatment T_2 mint crop was grown on beds and there was no proper availability of light and space to the mint crop so the herbage yield was less than mint in furrow as relay crop in bed planting wheat. Treatments T_4 and T_5, showes that mint crop was transplanted in the month of April due to higher temperature the herbage yield was decreased. The lowest value of the herbage yield shows in maize and mint intercropping this is because in this treatment the maize crops shows the good results in the intercropping as compare to the sole maize that is why in the intercropping of maize and mint, mint crop get suppressed and herbage yield was lowest in this treatment. It was found that herbage yield obtained from treatment T_1 was 13.8%, 6.2%, 19.5%, 29.3%, 39.5%, 31.7% greater than treatments T_2, T_3, T_4, T_5, T_6, T_7 respectively.

Oil yield and oil content

Mint sole that is T_1 shows the higher oil yield that were significantly differ with all other treatment this is because the plant population in this treatment were higher as compare to the other treatments that is why the sole mint showed higher results as compare to other treatments It was found that oil yield obtained from treatment T_1 was 12.7%, 5.5%, 18.3%, 24.6%, 36.9%, 29.7% greater than treatments T_2, T_3, T_4, T_5, T_6, T_7 respectively. Oil content was higher in treatment T_1 that is sole mint crop was grown in this treatment. All the treatments were non significantly differ from each other. The value of the oil content vary from 0.6% from all the treatments that were at par to all the treatments.

Grain yield (q/ha) of wheat

The result revealed that there was non significant difference observed between all the treatments (T_2, T_3, T_4, and T_5) at all observational periods. Numerically, grain yield was higher with T_4 treatment (45.68 q/ha) over T_2, T_3 and T_5 treatments at 30, 60, 90, 120 DAS and at harvest stage of crop. Whereas the lowest value of grain yield was observed in T_3 treatment at all intervals. Further, it was observed that at 30, 60, 90, 120 DAS and at harvest, the trend of grain yield was as $T_4 > T_5 > T_2 > T_3$ due to proper space for its growth, proper utilization of resources.

Grain yield (q/ha) of maize

Results indicate that intercropping of maize plus mint shows the higher grain yield as compare to the sole maize. The value of maize plus mint intercropping is 64.81 (q/ha) and sole maize is 60.58 (q/ha) but they donot reach the level of significance. The highest value of grain yield in intercropping system was due to more availability of resources, less weed competition that is why the grain yield is better in intercropping as compare to sole crop.

Agronomic advantages

Mint equivalent yield (q/ha)

The effect of intercropping on the maize equivalent yield (q/ha) is presented in Table 5. The data reveals that mint equivalent yield of mint was affected due to variations in the treatments. Treatment T_3 (mentha sown in furrow as relay crop in bed planted wheat) has maximum equivalent yield (300.53 q/ha) over the other treatments.

Land equivalent ratio (LER)
The table 5 shows the LER of the mint, wheat and wheat crops. This table revealed that the maximum LER was shown in treatment T_3 (mentha sown in furrow as relay crop in bed planted wheat) has higher LER (1.24) over the other treatments. The maximum LER was in intercropping rather than sole crop of mint, wheat and maize. The value above 1.0 indicating the advantage of all the intercropping systems over sole crops.

Table 5: Effect of intercropping on mint equivalent yield

Treatments	Mint equivalent yield (q/ha)	LER
T_1: Mentha sole	205.4	1
T_2: Mentha sown on beds as relay crop in bed planted wheat	288.2	1.17
T_3: Mentha sown in furrow as relay crop in bed planted wheat	300.53	1.24
T_4: Mentha on beds after harvesting of bed planted wheat	165.2	1
T_5: Mentha in furrow after harvesting of bed planted wheat	145.2	1
T_6: Maize plus mint on beds	269.61	1.19
T_7: Mint plus maize in furrow	282.39	1.2
T_8: Sole maize	-	1

Competitive indices
Area time equivalent ratio
The effect of intercropping on the Area time equivalent ratio is presented in Table 6. Perusal of the data reveals that area time equivalent ratio was affected due to variations in the treatments. Treatment T_7 (mentha plus maize in furrow) has maximum ATER (1.48) over the other treatments and the lowest ATER was shown in T_2 (1.15). Higher ATER in intercropped treatments with maize and mint crop was due to higher the availability of nutrients to the maize crop.

Monetary advantage index
The effect of intercropping on the monetary advantage index is presented in Table 6. The data reveals that monetary advantage index of was affected due to variations in the treatments. Treatment T_7 (mint plus maize in furrow) has maximum MAI (147392) over the other treatments.

Table 6: Effect of different treatment on Area time equivalent ratio (ATER) and Monetary advantage index (MAI)

Treatments	Area time equivalent ratio	Monetary advantage index
T_1: Mentha sole	-	-
T_2: Mentha sown on beds as relay crop in bed planted wheat	1.15	92224
T_3: Mentha sown in furrow as relay crop in bed planted wheat	1.18	113721
T_4: Mentha on beds after harvesting of bed planted wheat	-	-
T_5: Mentha in furrow after harvesting of bed planted wheat	-	-
T_6: Maize plus mint on beds	1.43	125184
T_7: Mint plus maize in furrow	1.48	147392
T_8: Sole maize	-	-

Conclusion
The result of the present field investigation entitled "Study on Mint (*Mentha arvensis*) intercropping with Maize (*Zea mays*) and Wheat(*Triticum aestivum*)" leads to the conclusion that mint growth, yield of sole mint (T_1) shows higher results than intercropping. In wheat and mint intercropping, mint crop shows the higher results after the harvesting of wheat crop after. Mint crop sown in nursery revealed that in the nursery the growth was higher but after the transplanting the growth and yield of crop was decreased due to transplanting shock in the field. Mint and maize intercropping shows the higher results as compare to sole maize.

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