CHAPTER 5
SUMMARY AND CONCLUSION

The present investigation entitled, “Studies on enhancing the productivity and profitability of wheat and mentha intercropping under different methods of crop establishment” was carried out under the Faculty of Agriculture and Forestry, Guru Nanak Dev University, Amritsar during the winter to summer seasons of the years 2006-07 and 2007-08. The experiments were conducted at village Dalla on the farm of Punjab Naujwan Kisan Sanstha member, Gurdaspur (Punjab) on silty clay loam soil. The studies involved testing the feasibility of intercropping mentha in wheat crop under flat and bed planted situations and its effect on productivity and profitability of wheat and mentha and to find out the optimum dose of nitrogen in intercropping system.

Two intercropping experiments on wheat (November sown) and mentha (February sown) namely, ‘Effect of intercropping and planting methods on the productivity of wheat and mentha’ and ‘Effect of crop establishment methods on yields of wheat and mentha intercropping under varied levels of nitrogen’ were carried out in randomized block design. In the first experiment, the treatments comprising two (T1), three (T2) and four (T3) rows of wheat with 20 cm row spacing and two rows of mentha on outer sides of wheat rows were planted covering a total width of 67.5, 135 and 135 cm in flat situation, respectively. Sole crop of wheat (22.5 cm row spacing) and mentha (60 cm row spacing) were sown under T4 and T5 in flat situation, respectively. Two (T6), three (T7) and four (T8) rows of wheat with 20 cm row spacing and two rows of mentha on outer sides of wheat rows were intercropped on the bed top covering a total width of 67.5 (37.5 cm top + 30 cm furrow), 135 (105 cm top + 30 cm furrow) and 135 (105 cm top + 30 cm furrow) cm in bed situation, respectively. Sole wheat at 20 cm row spacing (T9) and sole mentha with 60 cm row spacing (T10) were sown covering a total width of 67.5 cm (37.5 cm top + 30 cm furrow) and 120 cm (90 cm top + 30 cm furrow), respectively. In the second experiment, two planting methods viz. two rows of wheat with 20 cm row spacing and two rows of mentha on outer sides of wheat rows under flat and
bed (37.5 cm top+30 cm furrow) methods covering a total width of 67.5 cm were combined with five levels of nitrogen i.e. 0+0, 90+75, 120+75, 150+75 and 180+75 kg N ha$^{-1}$ to wheat and mentha, respectively. The summary of results is presented below experiment wise:

EXPERIMENT I

‘Effect of intercropping and planting methods on the productivity of wheat and mentha’

5.1 EFFECT OF INTERCROPPING AND PLANTING METHODS ON WHEAT

5.1.1 Emergence

The maximum emergence count of 171.4 and 160.7 seedlings m$^{-2}$ was recorded under ‘Flat Planted-Sole-Wheat’ during 2006-07 and 2007-08, respectively, which was significantly higher than all of the ‘Flat/Bed’ intercropping systems (ICS) as well as ‘Bed Planted-Sole-Wheat’. Emergence count did not differ significantly in all of the ‘Flat/Bed’ ICS during both the years.

5.1.2 Growth

5.1.2.1 Plant height

All the treatments were statistically on par with each other at 60 DAS during both years and at 90 DAS during first year of study. But in the later stages of growth, the plant height differed significantly under different treatments and in general, Flat planting (2:2) on 67.5 cm (T$_6$) and Bed Planting (2:2) on 67.5 cm (T$_6$) recorded higher plant height.

5.1.2.2 Dry matter accumulation (DMA) and total tillers

During both the years at 90 DAS, 120 DAS and at harvest stage, the maximum DMA was observed in Flat Planted Sole Wheat (T$_4$) which was significantly higher than all other treatments except Bed Planting (2:2) on 67.5 cm (T$_6$) and Bed Planted Sole Wheat (T$_9$). In ‘Flat/Bed’ ICS, the maximum DMA was in ‘Bed’ sown treatment (T$_6$) and in general it was significantly higher than other ‘Flat’ sown treatments (T$_1$, T$_2$ and T$_3$) at 90 DAS during 2007-08, 120 DAS and at the harvest stage during both the years. The maximum number of total tillers were recorded in Flat Planted Sole Wheat (T$_4$) which were significantly higher than all the ‘Flat/Bed’ ICS at all the stages during 2006-07 and 2007-08.
5.1.2.2.1 Crop growth rate (CGR) and relative growth rate (RGR)

During both the years at almost all the stages, except at 120 DAS - harvest stage, Flat Planted Sole Wheat (T_4) produced maximum CGR followed by T_6 and T_9. The RGR did not differ significantly due to various planting methods and ICS.

5.1.3 Yield attributes and yield

5.1.3.1 Yield attributes

The maximum number of effective tillers were recorded in T_4 during 2006-07 and 2007-08 i.e. 412.3 and 397.5 tillers m^{-2}, respectively, which were significantly higher than all the other treatments including ‘Flat/Bed’ ICS and Bed Planted-Sole-Wheat’. Amongst various intercropping systems, maximum number of effective tillers m^{-2} (336.5 and 327.1 during 2006-07 and 2007-08, respectively) were observed in Bed Planting (2:2) on 67.5 cm (T_6) followed by T_8, T_7, T_1, T_3 and T_2 in Year I and T_8, T_1, T_7, T_3 and T_2 during Year II. More ear length and higher number of grains per ear and test weight were observed in Bed Planting (2:2) on 67.5 cm (T_6) and Bed Planted Sole Wheat (T_9) over all the treatments during both the years.

5.1.3.2 Grain and straw yield

The maximum grain and straw yield of wheat was observed for Flat Planted Sole Wheat (T_4), which was on par with Bed Planted Sole Wheat (T_9) and Bed Planting (2:2) on 67.5 cm (T_6), and significantly greater than all other ‘Flat/Bed’ ICS. Among the ‘Flat/Bed’ ICS, the highest grain yield of wheat was produced with Bed Planting (2:2) on 67.5 cm (T_6) which was significantly higher than T_1, T_2, T_3 and T_7 during Year I and T_1, T_2, T_3, T_7 and T_8 during Year II. Similarly, the highest straw yield of wheat was produced with T_6 among various ‘Flat/Bed’ ICS during both the years.

5.1.4 Nitrogen content and its uptake

The per cent nitrogen content in grain and straw did not differ significantly in various ‘Flat/Bed’ ICS or ‘Flat/Bed’ ‘Sole’ crop during the two years. The Flat Planted Sole Wheat’ (T_4) produced significantly higher N uptake and total N uptake by grain over T_1, T_2, T_3 and T_7 during 2006-07 and T_1, T_2, T_3, T_7 and T_8 during 2007-08. In ‘Flat/Bed’ ICS, higher/significantly higher uptake of N by grain and straw and total N uptake was recorded in ‘Bed’ sown ICS as compared to ‘Flat’ sown ICS.
5.1.5 Profitability

The ‘Flat Planted-Sole-Wheat’ (T₄) gave the highest net returns during both the years which were significantly higher than T₁, T₂, T₃, T₇ and T₈ but was on par with other treatments. In ‘Flat/Bed’ ICS, the highest net returns of Rs 35102 and 35987 ha⁻¹ were observed in Bed Planting (2:2) on 67.5 cm (T₆) during 2006-07 and 2007-08, respectively. On pooled average basis, T₆ recorded 14.0, 14.0, 21.9, 23.8 and 43.4 per cent higher net returns over T₁, T₈, T₇, T₃ and T₂, respectively.

5.2 EFFECT OF INTERCROPPING AND PLANTING METHODS ON MENTHA

5.2.1 Growth

5.2.1.1 Plant height, stools and dry mater accumulation (DMA)

Among ‘Flat/Bed’ ICS, in Year I and II, the plant height, number of stools m⁻² and DMA of mentha was maximum in Flat Planted (2:2) on 67.5 cm (T₁) followed by Bed Planting (2:2) on 67.5 cm (T₆) at all the stages except at the harvest stage during Year II. It may be due to occurrence of rainfall between 120 DAS to harvest stage.

5.2.1.2 Crop growth rate (CGR) and relative growth rate (RGR)

All the treatments during Year I recorded an increase in CGR of mentha upto 120 DAS and which declined, thereafter. During Year II, T₁, T₆, T₇ and T₈ recorded an increase in CGR until the harvest stage. The maximum RGR of mentha was observed at 60 to 90 DAS and, thereafter, it decreased.

5.2.1.3 Leaf: stem ratio

During both the years at 90 and 120 DAS, Flat planting (2:2) on 67.5 cm (T₁) produced the highest leaf: stem ratio. However, during 2007-08, all the ‘Bed’ sown treatments recorded significantly higher leaf: stem ratio than the ‘Flat’ sown mentha due to higher rainfall.

5.2.2 Herbage and essential oil yield

Amongst ‘Flat/Bed’ sown ICS, the ‘Flat’ sown crop during the Year I and the ‘Bed’ during Year II gave higher herbage yield of mentha due to variation in rainfall. Of the various ‘Flat’ sown ICS, Flat planting (2:2) on 67.5 cm (T₁) produced the highest herbage yield during both the years which was significantly higher than both T₂ and T₃. In ‘Bed’ sown ICS, during both the years, the highest herbage yield of mentha was in Bed
Planting (2:2) on 67.5 cm (T₆) which was significantly higher than T₇ and T₈. Over the ICS, Flat planting (2:2) on 67.5 cm (T₁) produced the highest ‘Essential Oil Yield’ of 154.8 litres ha⁻¹ during 2006-07 which was significantly more than in T₂, T₃, T₇ and T₈ and on par with T₆. During 2007-08, T₅ Flat Planted Sole Wheat produced the highest ‘Essential Oil Yield’ of 136.8 litres ha⁻¹ which was significantly higher than all the ICS system except T₆.

5.2.3 Essential oil content (EOC) and its quality

During both the years, the per cent EOC did not differ significantly due to various ‘Flat/Bed’ ICS /sole crops. The quality parameters of essential oil viz. refractive index, specific gravity and optical rotation did not differ significantly due to various ICS or planting methods. Whereas, per cent menthol content differed marginally due to various intercropping and planting method treatments. These parameters were within the permissible limits of Indian Standard Institution.

5.2.4 Nitrogen content and its uptake

The per cent N content of mentha ranged from 1.66 to 1.70 during 2006-07 and from 1.61 to 1.66 during 2007-08, though the differences among various ‘Flat/Bed’ ICS were not significant. During 2006-07, the highest N uptake by mentha was observed for Flat Planted Sole Mentha (T₅) whereas, it was so in Bed Planted Sole Mentha (T₁₀/ Bed Planted Sole Mentha (T₅) during 2007-08. During both the years, the ‘Sole’ planted mentha (T₅/T₁₀) gave significantly higher N uptake than almost all the ICS due to higher DMA.

5.2.5 Profitability

The two year pooled data showed that the highest net returns of Rs. 46429 ha⁻¹ were observed for Bed Planted Sole Mentha (T₁₀) which were significantly higher than all the ‘Flat/Bed’ ICS intercropping systems and on par with T₅ (Rs.45568 ha⁻¹). In the ICS during both the years, the highest net returns of mentha were recorded under ‘Flat or ‘Bed’ having wheat+mentha (2:2 rows) on 67.5 cm (T₁/T₆). The most profitable intercropping option was Bed Planting (2:2) on 67.5 cm (T₆) and it recorded 4.8, 9.4, 14.6, 5.0 and 7.2 % higher net returns over T₁, T₂, T₃, T₇ and T₈, ICS, respectively.
5.3 YIELD ADVANTAGE PARAMETERS OF WHEAT-MENTHA INTERCROPPING SYSTEM

5.3.1 Wheat grain equivalent yield

During both the years and on two year pooled average basis, the maximum wheat grain equivalent yield of the ICS was recorded with ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ (T6).

5.3.2 Intercropping system profitability and benefit cost (B: C) ratio

In the ICS, maximum net returns of Rs. 69887, 82282 and 76085 ha⁻¹ were recorded with Bed Planting (2:2) on 67.5 cm (T6) during 2006-07, 2007-08 and on pooled average basis, respectively. However, during 2007-08 and on pooled average basis, the T6 produced significantly higher returns over all other treatments. In ‘Flat’ and ‘Bed’ planted treatments, T3 and T8 having wheat and mentha in 4:2 rows ratio, produced higher B: C ratio than in 3:2 and 2:2 row ratio in respective planting methods during both the years. All the ‘Bed’ sown ICS treatments showed higher B: C ratio than their respective ‘Flat’ ICS treatments but the differences were not significant.

5.3.3 Production efficiency (PRE)

The highest PRE of 297.4, 330.4 and 313.9 Rs ha⁻¹ day⁻¹ was observed with Bed Planting (2:2) on 67.5 cm (T6) during 2006-07, 2007-08 and on pooled average basis, respectively.

5.4 ASSESSMENT OF INTERCROPPING FEASIBILITY INDICES

5.4.1 Land equivalent ratio (LER) and land equivalent coefficient (LEC)

During both the years (1.95 and 1.94) and on pooled average basis (1.95), the maximum LER was recorded with Bed Planting (2:2) on 67.5 cm (T6) which was significantly higher over all other ‘Flat/Bed’ ICS. All the treatments recorded LEC of more than 0.25, thus confirming the suitability of intercropping of wheat and mentha.

5.4.2 Area time equivalent ratio (ATER)

The highest ATER (1.25 and 1.24) was observed with Bed Planting (2:2) on 67.5 cm (T6) during Year I and II, respectively. It was significantly higher than all other ‘Flat/Bed’ ICS. There was a overall net saving of almost 25 per cent in use of space and time compared to sole cropping.
**EXPERIMENT II**

‘Effect of crop establishment methods on yield of wheat and mentha intercropping under varied levels of nitrogen’

5.5 **EFFECT OF PLANTING METHODS AND NITROGEN LEVELS ON WHEAT**

5.5.1 **Emergence**

During both the years, the seedling emergence of wheat in ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ and ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ was on par. Graded levels of nitrogen applied to wheat also did not influence the emergence count significantly.

5.5.2 **Growth**

5.5.2.1 **Plant height**

The plant height of wheat, at all the stages during both the years, did not differ significantly due to planting methods. Increasing levels of nitrogen enhanced the plant height significantly up to 120 kg N ha$^{-1}$ ($N_{120}$) at all the stages. However, at highest rate ($N_{180}$), plant height was significantly higher over $N_{120}$ at 90 DAS during 2006-07 and at 120 DAS and harvest stage during 2007-08.

5.5.2.2 **Dry matter accumulation (DMA) and total tillers**

‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ accumulated significantly more dry matter of wheat than ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm ’ at all the stages. Increasing levels of nitrogen increased the DMA of wheat significantly up to $N_{120}$ at all the stages during 2006-07 and only at 120 DAS and harvest stages during 2007-08. During both the years at all the stages, the ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ produced significantly higher number of total tillers m$^{-2}$ over the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’. Increasing levels of nitrogen application enhanced the total tillers per unit area significantly up to $N_{120}$ and further increase, though, recorded higher number of total tillers but differences were not significant during 2006-07 and 2007-08.

5.5.2.3 **Crop growth rate (CGR) and relative growth rate (RGR)**

During Year I and Year II, ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ recorded significantly higher CGR of wheat over ‘Flat Planted Wheat + Mentha (2:2
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rows) on 67.5 cm’ at all the stages. The CGR of wheat increased as the N application increased from 0 to 180 kg ha\(^{-1}\) between 60 to 120 DAS during both the years, but between 120 DAS to harvest stage, it decreased from 0 to 90 kg ha\(^{-1}\) and again increased upto 150 kg ha\(^{-1}\) during 2006-07 and upto 180 kg ha\(^{-1}\) during 2007-08. During both the years at all the stages, except at 120 DAS to harvest stage during 2007-08, the RGR of wheat did not differ significantly due to planting methods. In general, the increase in N application increased the RGR upto N\(_{120}/N_{150}\) and further increase in N showed a marginal decline.

5.5.3 Yield attributes and yield

5.5.3.1 Yield attributes

‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ recorded significantly higher number of effective tillers, ear length, grains per ear and test weight over ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’. A significant increase in the number of effective tillers was recorded up to N\(_{120}\). Increasing levels of nitrogen increased the ear length up to N\(_{150}\) but further increase in N showed no significant difference. Increasing levels of nitrogen increased the number of grains per ear up to N\(_{120}\). During 2006-07, N\(_{120}\) application recorded the maximum test weight (39.14g) of wheat which was significantly higher than N\(_0\) and N\(_{180}\). During 2007-08, N application did not show any significant differential effect on the test weight.

5.5.3.2 Grain and straw yield

The ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ recorded significantly higher grain and straw yield of wheat than the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’. The ‘Bed’ sown wheat gave 14.2 and 18.7 per cent higher grain yield of wheat over the ‘Flat’ during 2006-07 and 2007-08, respectively. During both the years, by increasing the level of nitrogen, a significant increase in the grain yield of wheat was recorded upto 120 kg N ha\(^{-1}\) but further increase in N to 150 and 180 kg ha\(^{-1}\) did not enhance the grain yield significantly. A reduction in grain yield was observed at highest level of N i.e. 180 kg ha\(^{-1}\) during both the years. Interaction between planting methods and different nitrogen levels during both the years was significant.
Increasing rates of nitrogen application increased the straw yield of wheat up to $N_{150}$ during 2006-07 and up to $N_{180}$ during 2007-08. However, during both the years, the significant increase was obtained up to $N_{150}$ only.

### 5.5.4 Lodging percentage and lodging score

During 2006-07, flat planting gave higher lodging percentage and lodging score than the bed planted wheat but the differences were not significant. Higher level of $N_{180}$ recorded significantly higher lodging percentage and lodging score than $N_0$, $N_{90}$, $N_{120}$ and $N_{150}$.

### 5.5.5 Nitrogen content and its uptake

Significantly higher nitrogen content in grain and straw and N uptake by wheat was observed under ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ over the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’. Increasing levels of nitrogen increased the per cent nitrogen content in grain during Year I and Year II. The per cent nitrogen content in straw too increased with increasing levels of N but the response varied between the years. During both the years, the increasing levels of nitrogen increased the N uptake significantly by the grain up $N_{120}$ whereas the straw was increased significantly upto $N_{150}$ during Year I and upto $N_{120}$ during Year II.

### 5.5.6 Profitability

During Year I and II and on pooled average basis, ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ gave 19.2, 26.6 and 23.0 per cent higher net returns over the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’, respectively. On pooled average basis, the highest net returns of Rs 39128 per hectare were obtained under ‘Bed’+$N_{120}$ which was on par with ‘Bed’+$N_{150}$ and significantly higher than other combinations of planting methods x nitrogen levels. The ‘Flat’ responded significantly up to $N_{150}$.

### 5.6 EFFECT OF PLANTING METHODS AND NITROGEN LEVELS ON MENTHA

#### 5.6.1 Growth

### 5.6.1.1 Plant height, stools and dry matter accumulation (DMA)

During both the years except at 120 DAS during 2007-08 and at harvest during 2006-07, the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ recorded significantly higher plant height, number of stools m$^{-2}$ and DMA of mentha than the ‘Bed
Planted Wheat + Mentha (2:2 rows) on 67.5 cm’. All the treatments applied with N\textsubscript{75} to mentha crop recorded more plant height, number of stools and DMA than the control (N\textsubscript{0}) at all the stages during both the years.

5.6.1.2 Crop growth rate (CGR) and relative growth rate (RGR)

During 2006-07 and 2007-08 from 60 to 90 DAS, the ‘Flat’ recorded significantly higher CGR of mentha than the ‘Bed’. But, at 120 DAS to harvest stage during 2007-08, the ‘Bed’ recorded significantly higher CGR than the ‘Flat’ due possibly to higher rainfall. During both the years at all the growth stages, except at 60 to 90 DAS and 120 DAS to harvest stage during 2007-08, all the N levels (N\textsubscript{75} to mentha) recorded significantly higher RGR of mentha over the control.

5.6.1.3 Leaf: stem ratio

During 2006-07 and 2007-08, at 90 and 120 DAS, the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ recorded significantly higher leaf: stem ratio of mentha than the ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’. Reversely, at the harvest stage during 2007-08, the ‘Bed’ recorded significantly higher leaf: stem ratio over the flat. During both the years, at all the stages, nitrogen application to wheat crop did not show any carry over response on the leaf: stem ratio of mentha. But, the N application to the mentha crop was effective.

5.6.2 Herbage and essential oil yield

During 2006-07, the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ recorded 1.7 per cent higher herbage yield of mentha than the ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ but the differences were not significant. However, during 2007-08, ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ gave significantly higher herbage yield by 5.6 per cent over the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’. During both the years, all the levels of N application at N\textsubscript{90}/N\textsubscript{120}/N\textsubscript{150}/N\textsubscript{180} to wheat + N\textsubscript{75} to mentha were on par in the herbage yield of mentha but all these levels were significantly higher than the control.

Differences in the ‘Essential Oil Yield’ were not significant due to ‘Flat/Bed’ planting methods during 2006-07, but the ‘Flat’ showed an marginal edge over ‘Bed’ by 2.6 per cent. During, 2007-08, ‘Bed’ method recorded significantly higher ‘Essential Oil Yield’ of mentha by 8.5 per cent than the ‘Flat’ method due to higher herbage yield.
Graded levels of N application to wheat did not show any significant impact on the essential oil yield of mentha. But, the application of N to mentha had a significant impact on the essential oil yield of mentha. All the treatments having N$_{75}$ to mentha crop recorded significantly higher essential oil yield over control (N$_0$) during both the years.

5.6.3 Essential oil content (EOC) and its quality

During Year I, the ‘EOC did not differ significantly due to planting methods. However, in Year II, ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ recorded significantly higher EOC over the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’. Graded levels of N application to wheat did not influence the EOC of mentha. During both the years, quality parameters of essential oil of mentha viz. refractive index, specific gravity and optical rotation did not differ significantly due to planting methods and nitrogen levels. There was not much variation in the per cent menthol content due to various rates of nitrogen application. However, the no application of N recorded slightly higher menthol content per cent during both the years.

5.6.4 Nitrogen content and its uptake

During both the years, the N content of mentha did not differ significantly due to planting methods. During 2006-07, the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ recorded marginally higher N uptake over the ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ but the differences were not significant. During 2007-08, the ‘Bed’ showed significantly higher N uptake by mentha than the ‘Flat’. All the treatments with N$_{75}$ to mentha crop recorded significantly higher per cent N content and uptake of mentha over N$_0$.

5.6.5 Profitability

The pooled data of net returns of mentha revealed that ‘Bed’ sown mentha recorded 4.9 per cent higher net returns over the ‘Flat’ but the differences were not significant. During both the years, various rates of N application to wheat had no carry over impact on the net returns of mentha but the effect of N application to mentha crop was significant and N application to mentha at 75 kg ha$^{-1}$ gave significantly higher net returns over the control (N$_0$). The data pooled for two years also recorded similar results.
5.7 OPTIMUM DOSE OF NITROGEN AND NITROGEN USE EFFICIENCY IN WHEAT-MENTHA INTERCROPPING SYSTEM

5.7.1 Optimum dose of nitrogen

The optimum dose of fertilizer N for wheat-mentha intercropping system under ‘Flat’ and ‘Bed’ sown situation was 238.9 and 208.7 kg ha\(^{-1}\), respectively.

5.7.2 Apparent N recovery (ANR)

During both the years and on pooled average basis, ‘Bed’ recorded significantly higher ANR over ‘Flat’. The per cent ANR decreased as the N application increased from ‘Wheat N\(_{90}\) + Mentha N\(_{75}\)’ to ‘Wheat N\(_{180}\) + Mentha N\(_{75}\)’ kg ha\(^{-1}\) during both the years. Interactive impact of planting method x nitrogen levels was significant on ANR.

5.7.3 Agronomic efficiency (AE)

During Year I, Agronomic efficiency of both the planting methods did not differ significantly. During Year II and on two year pooled average basis, ‘Bed’ recorded significantly higher AE over ‘Flat’. The highest AE of 29.0, 24.7 and 26.8 kg grain kg\(^{-1}\) N applied was recorded under ‘Wheat N\(_{90}\) + Mentha N\(_{75}\)’ during 2006-07, 2007-08 and on pooled average basis, respectively.

5.7.4 Physiological efficiency (PE)

During both the years, Physiological efficiency of the wheat-mentha ICS did not differ significantly due to planting methods but various N levels had a significant impact and it declined with increase in N application due to more loss and less utilization of applied N by the crops.

5.8 YIELD ADVANTAGE PARAMETERS OF WHEAT-MENTHA INTERCROPPING SYSTEM

5.8.1 Wheat grain equivalent yield

During 2006-07, 2007-08 and on pooled average basis, the ‘Bed planted wheat + mentha (2:2 rows) on 67.5 cm’ recorded wheat grain equivalent yield of 127.6, 134.2 and 130.9 q ha\(^{-1}\) which was higher by 2.8, 11.7 and 7.2 per cent, respectively, over the ‘Flat planted wheat + mentha (2:2 rows) on 67.5 cm’. On two year pooled average basis, increasing levels of N application enhanced the wheat grain equivalent yield significantly upto 120 and 75 kg N ha\(^{-1}\) to wheat and mentha, respectively.
5.8.2 Intercropping system (ICS) profitability

During Year I and II and on pooled average basis, the ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ showed significantly higher net returns of wheat-mentha ICS than the ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ by 5.5, 17.5 and 11.9 per cent, respectively. Maximum pooled net returns of Rs 86188 ha$^{-1}$ in wheat-mentha ICS were recorded under ‘Wheat N$_{120}$+Mentha N$_{75}$’ in combination with the ‘Bed Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ which were higher by 11.3 per cent over ‘Flat Planted Wheat + Mentha (2:2 rows) on 67.5 cm’ with N$_{150}$+Mentha N$_{75}$’ kg ha$^{-1}$.

5.8.3 Benefit cost (B: C) ratio

The ‘Bed’ recorded higher B: C ratio than the ‘Flat’ during both the years and on two year pooled average basis. The B: C ratio of the wheat-mentha ICS increased with increase in application of N up to ‘Wheat N$_{120}$+Mentha N$_{75}$’ during 2006-07 and up to ‘Wheat N$_{150}$+Mentha N$_{75}$’ during 2007-08 and further application only enhanced the cost and not the benefit.

5.8.4 Production efficiency (PRE)

The ‘Bed’ recorded significantly higher Production efficiency (Rs ha$^{-1}$day$^{-1}$) over the ‘Flat’ during both the years due to higher wheat grain equivalent yield of ICS. Increase in application of N, generally, enhanced the PRE up to ‘Wheat N$_{150}$+Mentha N$_{75}$’, thereafter; it decreased at higher rate of N, possibly due to more loss of applied N at higher levels.

CONCLUSION

- The intercropping of wheat+mentha (2:2) on 67.5 cm bed was observed to be agronomically compatible, technically feasible and economically viable option in silty clay loam soils of average fertility. This system produced significantly higher wheat grain equivalent yield (139.4 q ha$^{-1}$) and net returns (Rs 76085/- ha$^{-1}$) over other crop establishment methods and was found to be suitable particularly under adverse weather conditions of late rains.

- In wheat-mentha intercropping system, the maximum net returns of Rs 86188 ha$^{-1}$ were recorded with bed planting using nitrogen @ 120 kg ha$^{-1}$ to wheat + 75 kg ha$^{-1}$ to mentha which gave higher returns by 11.3 per cent than flat sowing at the
same level of nitrogen. However, application of nitrogen to wheat had no carry over effect on growth, yield and quality of mentha.

- The optimum dose of nitrogen for wheat-mentha intercropping system under flat and bed sown condition was observed to be 238.9 and 208.7 kg ha$^{-1}$, respectively.
- All the treatments produced land equivalent ratio of more than one, which confirmed the suitability of intercropping of wheat and mentha.
- The data on area time equivalent ratio indicated that there was an overall net saving of 25% in use of space and time compared to sole planting.

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