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Effects of nitrogen fertilization and rice harvest height on agronomic yield indices of ratoon rice–berseem clover intercropping system

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Abstract

To determine the effect of nitrogen, main crop harvest height of rice and intercropping of berseem clover (*Trifolium alexandrinum* L.) with rice ratoon (*Oryza sativa* L.) on agronomic yield indices a series of field experiments were conducted at different dates in 2007-2008 and 2008-2009. The experimental design was a split-split plot with randomized complete block design with three replications. Accordingly, three levels of N (0, 35 and 70 kg ha^{-1}) in main plots, two planting dates of berseem clover (coincident with main crop harvest and 40 days after it) in sub plots and two harvesting heights (10 and 40 cm above the soil surface) in sub-sub plots were laid out. The application of 70 kg N ha^{-1} and short harvest height (10 cm) yielded the highest ratoon rice grain, ratoon days to 50% heading and harvest index. The best biological yield was obtained from higher harvest height as well. Qualitative traits such as gelatinization temperature (GT) and protein content (PC) increased with large amount of N. But amylose content (AC) and gel consistency (GC) were not affected by experimental treatments. Effect of nitrogen and harvest height on fresh and dry weight of both cuts, protein content in the first cutting and total land equivalent ratio (LER) were significant at 1% level. The highest fresh and dry weight yield was obtained by application of 35 kg N ha^{-1}. The highest protein and total LER obtained from higher N application (70 kg N ha^{-1}). All studied traits had the highest value in shorter harvest height and the first planting date of berseem clover.

Keywords: Nitrogen, Harvest height, Intercropping, Berseem clover, Ratoon rice.
Abbreviations: GT- Gelatinization temperature; PC- Protein content; AC- Amylose content; GC- Gel consistency; LER- Land equivalent ratio; ANOVA- Analysis of variance; AAOCC- American association of cereal chemists.

Introduction

Rice is one of the most important grains in the world and is the second most important food in Iran (Nasiri and Pirdashti, 2003). It is grown widely in all continents, especially in Asia. While the cultivation area of rice in Iran is so smaller compared to other crops including wheat (*Triticum aestivum* L.), it is of great importance in the north of Iran, especially in Mazandaran and Guilan provinces with totally 78% of cultivation area and rice yield (Nasiri and Pirdashti, 2003; and Daliri et al., 2009). Due to land and water limitation, several methods have been suggested to increase yield per unit of area including ratoon cultivation (Santos et al., 2003), and cultivation of different plants such as berseem clover, canola, cabbage in rotation with rice on paddy fields (Yani et al., 1997; Nasiri et al., 2008) and intercropping (Stout et al., 1997; Vasilakoglou and Dhima, 2008). Ratooning, the practice of grain harvesting from tillers originating from the stubble of a previously harvested crop, enhances rice yield without increasing land area (Mengle and Wilson, 1981; Turner and Fund, 1993). Ratoon not only increases farmer's income but also results in efficiency and effective use of resources per land/time unit (Santos et al., 2003; Dustin et al., 2009). Ratoon enjoys various benefits such as low production cost, short growth period and high cooking quality (Dustin et al., 2009). Moreover, ratoon crop may be grown with 50% less labor. Neither land preparation nor transplanting is needed. Meanwhile, the crop uses 60% less water than the main crop and the yield of the ratoon crop may be achieved by 50-70% of the main crop (Oad et al., 2002). Satisfactory yield of ratoon rice depends on varieties, seasonal requirements, optimum fertilizer dose, time of fertilization, cutting height, planting date and spacing of main crop, harvesting date of main crop, water and pest management and etc. (Jones and Snider, 1987; Santos et al., 2003). Among different factors, applications of fertilizers and cutting height have the prominent role in the performance of ratoon rice (Mochizuki et al., 2001; Bond and Bollich, 2006). According to Begum et al. (2002), cultivation and cultural practices, including cutting height and fertilizer management, which provide a large quantity of reserves at harvest may be advantageous for rice ratooning. Some previous studies show that the ratoon rice grain yield is increased by applying nitrogen after harvesting the main crops (Bahar and De Datta, 1977; Mengel and Wilson, 1981; Oad et al., 2002). Meanwhile, Balasubramanian and Ali, (1990) observed that yield of ratoon crop increased with the increasing rate of nitrogen up to 125 kg ha^{-1}. As reported by Chuang and Ding (1992), the application of nitrogen fertilizer by 140 kg ha^{-1} produced better ratoon yield (increase 12.8 – 16.1%). Application of 100 kg ha^{-1} nitrogen produced high quality rice. Although application of nitrogen is a major factor to produce acceptable rice grain yields, excessive application of N can have negative results (Wells and Johnston, 1970; Jason et al., 2005; Bond and Bollich, 2006). Performance of ratoon rice is also affected by cutting height. The ratoon tiller regeneration and growth depend on the number of buds which remain on the stubbles (Oad et al., 2002). Prasher (1970) mentioned that the tiller number of the ratoon crop increases with increasing in the cutting height. He reported that tillers regenerated from higher nodes formed more quickly, grew faster and matured earlier. Further to this, Dustin et al. (2009) expressed that cutting at appropriate height had a positive effect on ratoon yield. Ting and Liu (1996) suggested that most ratoon yield was produced in cutting height at 5 cm. Calendacion et al. (1991) reported that a lower cutting tended to increase grain yield but prolonged maturity. Several researches have been conducted about cultivation of berseem clover as second crop in rotation with rice in many paddy field regions in the world (Yanni et al., 1997; Ranjbar, 2007; Nasiri et al., 2008). Also, there were several reports about intercropping of berseem clover with other small grain cereals (Juskiw et al., 2000), with annual ryegrass and annual legumes (Thompson and Stout, 1997; Stout et al., 1997) and with pulse crops (Jedel and Helm, 1993). A little information is available on the performance of ratoon rice-berseem clover intercrops. Potential benefits of berseem clover, intercropping with cereal, include increased yield, greater yield stability, increased protein and forage quality, improved sustainability through biological N fixation, reduced fertilizer needs, reduction of weed competition, increased soil organic matter, and increased subsequent crop yield (Stout et al., 1997; Ghaffarzade, 1997; Anil et al., 1998; Qamar et al., 1999; Mohsenabadi et al., 2008). Chen et al. (2004) observed that barley-pea intercropping increased the total yield and protein content of the forage compared to sole barley cultivation. Different experiments (Ghaffarzade, 1997; Yanni et al., 1998; Sheaffer et al., 2001) showed that berseem clover provided N for subsequent crop. Ghaffarzade (1997) reported that berseem clover-barley intercrop was influenced by N fertilizer treatments. Higher hay yields were obtained from the 168 kg ha^{-1} N treatment compared to unfertilized check plot. According to Mohsenabadi et al. (2008), nitrogen enhanced the forage yield, grain yield, crud protein content, and crud protein yield of barley and vetch in sole and intercrops. Intercropping of berseem clover with ratoon rice increase ratoon rice yield and improve forage yield in winter pasture. This system is very important in Iran because of increasing population and inadequacy of forage production. Rice sequential cropping is common in the paddy fields in the north of Iran due to marsh land. In recent years, second crop cultivation such as clover, potato, canola, cabbage and vegetable crops were cultivated with rice rotation in high level regions (Nasiri et al., 2008). The utilization of resources is high when it is possible to plant two crops, berseem clover and rice, as intercropping. As mentioned earlier, information about berseem clover-ratoon rice intercrops is rare. The objectives of the present research are to determine (1) the effect of N fertilizer rate on ratoon rice and berseem clover, (2) effect of the cutting height of main crop on production of ratoon rice and berseem clover, and (3) the feasibility of intercropping the berseem clover with ratoon rice to produce ratoon rice grain yield and forage in winter and spring.

Materials and methods

Field experiment and treatments

The experiments were conducted on Islamic Azad University farm research center (36°59`N, 52°55`E) located in Joybar of Mazandaran province, Iran during the years 2007-2009. The previous crop grown in the field was rice and the same field was used for the experiment in both years of the study. The practice of land preparation was carried out according to conventional procedure. The basal fertilizers for the main crop were added to each plot in both years according to soil test. Three days before transplanting, the field received 90 kg N ha^{-1} and 80 kg K2O ha^{-1} in 2007 and 69.5 kg N ha^{-1} and 60 kg K2O ha^{-1} in 2008, respectively. One third of N basal fertilizer was distributed by hand, and the fertilizers were incorporated into the soil in such a way to allow pudding. The main crop was top-dressed with $^2/_3$ and $^1/_3$ of remaining N fertilizer in each year at the active tillering and panicle initiation stage, respectively. The plot size was 10 m^{-2}. 45-day-old seedlings were transplanted into the experimental plots at rate of three seedlings $hill^{-1}$ on the third and first of May in 2007 and 2008, respectively. Rice was transplanted in 25 × 25 cm planting space. The main crop was harvested manually at moisture content of approximately 14%. Main crop harvesting date was the third of August in 2007 and the fifth of August in 2008. The experiment had a 3 (Nitrogen levels) x 2 (Planting date of berseem clover) x 2 (cutting height) factorial design, arranged in a randomized complete block Split-Split-Plot design with three replicates. The main plot, sub plot and sub-sub plot factors were nitrogen, planting date of berseem clover and cutting height, respectively. Rice and berseem clover seeds were disinfected by fungicide prior to planting. Berseem clover seed was inoculated by a appropriate *Rahizobium trifolii* and seeded at 25kg ha^{-1} and 30 kg ha^{-1} in the first and second planting date, respectively (added to the amount of seed at rate of 20% to second planting date) based on experimental treatments. Intercultural operations such as weeding, water management and plant protection were done when required to ensure and maintain the normal growth of main crop and ratoon rice berseem clover intercrops. Irrigation interval adjusted every 6 days.

Weather and soil conditions

The trial location was a moderate area (according to the Koppen climate classification). The meteorological data recorded during the trial period in each growing season is given in Table 1. During the growth, mean temperature in both years differed widely from normal temperature ranges. The mean temperature in January in 2007 was -1.6 °C when the weather was unusually cold according to 30 years mean temperature of 3.1 °C. In order to determine the physical and chemical properties of soil, samples were taken in experimental fields. The soil texture was Sandy-Loam and organic matter was 1.9 and 2.99 in the years 2007 and 2008, respectively. Table 2 shows the details of soil properties in each year.

Plant sampling and measurements

Days to 50% heading of ratoon was determined by calculating the time period from main crop harvesting until

Table 1. Monthly temperature and precipitation during the growing season during 2007-2009.

Months	Average temperature (^oC)						Total precipitation (mm)	
	Minimum		Maximum		Mean			
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
May	13.6	14.2	21.8	24.4	17.7	19.3	16.6	21.1
June	20.2	18.8	31.0	28..4	25.6	23.6	13.5	18.9
July	21.9	21.9	29.1	30.1	25.5	26.0	31.7	22.4
August	23.1	23.8	32.9	32.8	28.0	28.3	0.1	5.7
September	20.6	22.8	32.2	32.4	26.4	27.6	17.6	26.4
October	15.5	18.3	26.1	26.3	20.8	22.3	61.5	93.4
November	11.1	10.2	21.5	18.4	16.3	14.3	31.5	71.6
December	3.0	6.4	14.9	15.2	8.9	10.8	157.0	126.3
January	-1.6	2.7	7.9	11.5	3.15	7.7	31.1	50.0
February	1.0	5.2	10.0	14.2	5.5	9.7	46.1	106.1
March	6.1	7.7	17.6	16.9	11.9	12.3	30.1	18.6
April	11.4	8.7	22.4	16.7	16.9	12.7	2.8	14.6

50% of rice had visible panicles. Harvesting date of ratoon rice was the 21th and 10th of October in 2007 and 2008, respectively. Ratoon rice grain yield was determined from harvest area of $5m^2$ adjusting to 14% moisture content. Biological yield and harvest index were calculated from each plot. Amylose content (AC) of milled rice was measured using the colorimetric iodine assay index method (Juliano, 1971). Gelatinization temperature (GT) is determined based on the time required for cooking milled rice (Little et al., 1958). Gel consistency (GC) is determined through heating a small quantity of rice in a diluted alkali (Cagampang et al., 1973). Nitrogen was assessed by the Kjeldahl mixed Cu/Ti catalyst method and multiplied by 6.25 for protein content (PC) (AAOCC, 1996). Fresh and dry weight yield of berseem clover was determined from a 4 m^2 area. Cut1 was measured in late December before the onset of winter, and Cut2 harvested in early May, two weeks before rice transplanting. Percentage of crude protein was calculated via Kjeldhal and Fiber method (Undersander et al., 1993). Land equivalent ratio (LER) was computed by the following formula. LER= (Crop A yield in intercropping/Crop A yield in single cropping) + (Crop B yield in intercropping/ Crop B yield in single cropping).

Statistical analysis

Main and interaction effects of experimental factors were determined by the analysis of variance (ANOVA) using the GLM procedure in SAS (SAS institute, 2002). The assumptions of variance analysis were tested ensuring that the residuals were random, homogenous, with a normal distribution with a mean of zero. The significant of differences among treatment means were tested using LSMEANS with the PPIFF option. Pearson correlation coefficients were calculated using the PROC CORR in SAS.

Results and discussion

Weather condition

As Table 1 shows, temperature differed in both growing seasons, as minimum and maximum average temperature in 2008 was higher than that of 2007. Minimum mean temperature in early January was lower compared to the 30 year average (3.1^oC) in 2007 (-1.6^oC) and according to meteorological data, this cold was unprecedented during the last fifty years. So berseem clover was completely spoiled by the cold weather and we had no data of berseem clover in 2007. But it was quite normal in 2008 (2.7^oC). Significance for N fertilizer applications, cutting heights, planting dates of berseem clover and interaction effects for each parameter are presented in various tables (Tables 3, 4, 5, 6). The treatment ×year interaction effect was significant for all measured traits. Therefore, the results are presented for each year separately.

Ratoon days to 50% heading, ratoon rice grain yield, biological yield and harvest index

All the aforementioned traits were significantly influenced by the main effects of N fertilizer, cutting height and two-way interactions between them for both years, except for N fertilizer rates on harvest index. The main effect of planting dates of berseem clover and interaction between them were not significant for all traits in both years. Therefore, the data in Table 3 is presented as the main effects of N fertilizer rates, cutting height and two-way interactions. Mean compa-ison of treatments indicate that the highest ratoon rice grain yield and biological yield were produced by 70 kg N ha^{-1} in both years. Ratoon rice grain yield had positive correlations with 1000 grain weight ($r=0.67$, $p<0.01$), panicle length ($r=0.65$, $p<0.01$), the number of effective tillers $hill^{-1}$ ($r=0.72$, $p<0.01$), and filled spikelet's $panicle^{-1}$ ($r=0.81$, $p<0.01$). Furthermore, there was also a close relationship between Plant height at maturity and total tillering $hill^{-1}$ with biological yield ($r=0.62$, $p<0.01$; $r=0.88$, $p<0.01$, respectively). The response to N fertilizer rate reported here was similar to those of other researchers (Bahar and De Data, 1977; Mengel and Wilson, 1981; Jason et al., 2005; Bond and Bollich, 2006). The influence of N fertilizer rate from 0 to 70 kg ha^{-1} delayed the ratoon days to 50% heading by 4 and 3 days in 2007 and 2008, respectively. Bond and Bollich (2006) reported an N fertilizer application rate 90lb/acre followed by immediate flooding produced the highest ratoon rice grain yield and increased delayed ratoon days to 50% heading. Increased vegetative growth, lodging, disease damage, delayed maturity and reduced grain yield of lower quality can occur if N application is made at unnecessary rates or to rice at the wrong stage (Wells and Johnston, 1970; Bond and Bollich, 2006). Ratoon rice grain yield, biological yield, harvest index and ratoon days to 50% heading were significantly ($P<0.01$) affected by cutting height, except for ratoon rice grain yield in 2007 (Table 3). Result showed that ratoon days to 50% heading decreased with increasing

Table 2. Physico-chemical properties of the soil.

Soil properties	2007	2008	2009
EC (dSm^{-1})	1.39	0.97	1.11
pH	7.82	7.66	7.78
Saturation percentage (%)	30.00	24.55	22.00
Organic matter (%)	1.94	2.99	3.36
Organic carbon (%)	0.13	1.74	14.20
Available P(P.P.M)	18.10	36.00	26.30
Available K (P.P.M)	38.00	31.00	34.00
Sand (%)	66.00	72.00	61.00
Silt (%)	26.00	23.00	29.00
Clay (%)	8.00	5.00	10.00
Soil texture	S.L	S.L	S.L

cutting height. Reduction of cutting height from 40 to 10 cm delayed ratoon days to 50% heading by 7 and 5 days during the years 2007 and 2008, respectively. Jones (1993) reported that the lowest cutting height can cause delayed maturity and increase in ratoon days to 50% heading. When the main crop was harvested at 10 cm cutting height, ratoon rice grain yield was increased by 2236.3 kg ha^{-1} in 2008. Grain yield was not improved in 2007 using the low (10 cm) cutting height (Table 3). Decreasing in ratoon rice grain yield in high cutting height (40cm) was reported by Dustin et al. (2009). Calendacion et al. (1991) indicated a lower cutting, tended to increase grain yield but prolonged maturity. Balasubramanian and Ali, (1990) reported that height of cutting had no effect on grain yield but greatly influenced the straw yield. The cutting height had a significant effect on biological yield and harvest index. Averaged over both years, biological yield was greater in 40 cm in both years but it was just the opposite in harvest index. Result of this research is parallel with those of other researchers (Mochizuki et al., 2001; Daliri et al., 2009). Increasing in biological yield can be due to high number of tiller per hill in higher cutting height (Prasher, 1970; Bahar and De Data, 1977; Daliri et al., 2009). In the present study, the correlation coefficient of biological yield with total tillering $hill^{-1}$ was 0.88 ($P<0.01$) which is consistent with the findings of Oad et al. (2002) and Daliri et al. (2009). Results of two fold interaction of N fertilizer rates and cutting height on grain yield of ratoon crop and ratoon days to 50% heading were significant, but biological yield and harvest index were unaffected by it in both years. As shown in Table 3, average of ratoon days to 50% heading, grain yield and harvest index in each N fertilizer rates were greater for H1 over both years, except for ratoon grain yield in 2007. The highest grain yield, harvest index and ratoon days to 50% heading were found from 75 kg N ha^{-1} and 10 cm cutting height interaction, while biological yield was higher in 40 cm cutting height in the same amount of N fertilizer. Mochizuki et al. (2000) indicated that grain yield of ratoon crop and biological increased with increasing cutting height and N fertilizer application. As observed by Dustin et al. (2009), when the main crop stubble was harvested at less cutting height (20 cm in comparison with 40cm), ratoon rice grain yield was the highest in all cultivars. Nakano and Morita (2008) found that the total dry matter was not affected by cutting height. In the present research, this report was supported by the positive and significant relationship observed between the number of effective tillers and percentage of filled spikelet with ratoon rice grain yield ($r = 0.72$, $P<0.01$; $r = 0.82$, $P<0.01$, respectively). Variance analysis showed that all studied traits could better use the resources and were higher in 2008 compared to the year 2007. Perhaps, more favorable weather condition and improvement of physico-chememical properties of soil in 2008 caused the increasing resource-use coefficient. Ichii (1982) found that ratoon rice grown at 30°C produced a higher dry weight than that in plants grow at 20°C. In addition, grain yield at 20°C was significantly lower than yields at high and normal temperature due to high spikelet sterility. Temperature also affects duration of ratoon rice growing. Crop maturity lengthens from 56 days at high temperature to 96 at low temperature (Ichii, 1982; Ziska, 1997; Chawhan et al., 2008).

Amylose content, gel consistency, gelatinization temperature and protein content

The main effect of nitrogen fertilizer factor was significant on gelatinization temperature (GT) and protein content (PC) in 2007 and 2008. But it had no effect on amylose content (AC) and gel consistency (GC). The main effect of other experimental factors and interactions between them were not significant for all quality traits for both years. In both years, protein content (PC) and gelatinization temperature (GT) response to N fertilizer rates showed a positive relationship and they increased with increasing N fertilizer applied to the ratoon crop. In the present study, the highest rate of protein content and gel-temperature (GT) were obtained from 70 kg N ha^{-1}. The results are in agreement with those of and Perez et al. (1996) Samonte et al. (2006) in that an N application can improve the quality traits of rice. Overall, in both years, amylose content (AC) and gel consistency (GC) were unaffected by all the N fertilizer treatments (Table 4). Mean comparisons of treatments indicated that amylose content (AC) under all N fertilizer treatments in 2007 was higher than that in 2008. However, the result of gel consistency was exactly the opposite. More amylose content in 2007 probably resulted in less temperature (Table 4). The negative correlation between amylose content and positive relationship of gelatinization temperature with environment temperature was reported by other researchers (Tashiro and Ebata, 1975; Chowdhury and Wardlaw,1978; Tashiro and Wardlaw, 1991). Tashiro and Wardlaw (1991) and Savin et al. (1996) observed that environmental conditions such as temperature during ripening stage influenced on amylose content and gel-temperature. They noticed that high temperatures during grain development tend to decrease in amylose content and increase in GT in rice grain. Dela Cruz et al. (1982) found that the temperature had a negative relationship to the content of amylose while gel consistency and gel-temperature (GT) had no relationship to it. The Result showed that there were significant effects of two-way interactions of N fertilizer rates and planting dates of berseem clover on gelatinization temperature and protein content. But amylose content and gel consistency were unaffected by it in both years. As shown in Table 4, gelatinization temperature and protein content in each N fertilizer rates were the highest for T1. Mean comparison of treatments indicated that the highest gelatinization temperature and protein content pertained to N2T1 (75 kg N ha^{-1} and the first planting date of berseem clover). Positive effect of application of N fertilizer on gelatinization temperature and protein content were reported by other researchers (Perez et al., 1996; Samonte et al., 2006; Almodares et al., 2009).

Fresh and dry weight, percentages of berseem clover crud protein and fiber

The main effects of all experiment factors were significant for all noted traits in both Cuts, except for N fertilizer treatment on fiber in Cut1 and crud protein in Cut2 and

Table 3. Mean comparison of nitrogen (N) and cutting height (H) on ratoon day to 50% heading, ratooning grain yield, biological yield, and Harvest index in 2007 and 2008.

Treatments*	Ratoon day to 50% heading		Ratooning grain yield		Biological yield		Harvest index	
	2007	2008	2007	2008	2007	2008	2007	2008
N0	42.50b	37.50b	816.3c	1153c	2170.9c	3005.2c	37.60a	38.37a
N1	44.58a	39.25a	1575.8b	2526.6b	4149.9b	6425.3b	37.97a	39.42a
N2	45.33a	39.25a	1822.6a	2828.2a	4711.1a	7113.7a	38.69a	39.9a
H1	47.33a	41.06a	1393.8a	2236.3a	3559.9b	5247.5b	39.20a	42.32a
H2	40.94b	36.28b	1415.9a	2102.1b	3794.7a	5781.9a	37.31b	36.36b
N0H1	44.83b	39.33b	793.0d	1179.6e	1999.4e	2895.1d	39.66a	40.74ab
N0H2	40.17c	35.67c	839.6d	1126.4e	2342.5d	3115.2d	35.84c	36.16b
N1H1	48.17a	41.67a	1544.7c	2591.7c	3983.8c	6072.3c	38.77ab	42.68a
N1H2	41.00c	36.83c	1606.9b	2461.4d	4316.0b	6778.3b	37.23b	36.31b
N2H1	49.00a	42.17a	1843.8a	2937.7a	4696.4a	6775.1b	39.26a	43.36a
N2H2	41.67c	36.33c	1801.4a	2718.6b	4725.6a	7452.3a	38.12ab	36.48b

For a given year LSMEANS within each column of each section followed by the same letter are not significantly different ($p<0.05$)
*N0: Without N application; N1: 35 kg N ha^{-1}; N2: 70 kg N ha^{-1}; H1: 10 cm cutting height; H2: 40 cm cutting height.

Table 4. Effects of nitrogen (N), berseem clover planting date (T) and cutting height (H) on Amylose, Gel consistency, Gelatinization temperature and Protein content of ratoon rice seed in 2007 and 2008.

Treatments*	Amylose (%)		Gel consistency		Gelatinization temperature		Protein (%)	
	2007	2008	2007	2008	2007	2008	2007	2008
N0	21.91a	18.27a	40.75a	45.63a	4.23b	4.76b	9.03c	9.95c
N1	22.12a	18.73a	41.58a	45.83a	4.45a	5.07a	9.49b	10.29b
N2	22.38a	18.43a	41.83a	47.17a	4.59a	5.1a	9.99a	10.54a
T1	22.20a	18.51a	42.06a	46.88a	4.98a	5.12a	9.54a	10.30a
T2	22.07a	18.49a	41.39a	45.89a	4.31a	4.86a	9.46a	10.23a
H1	22.25a	18.59a	42.05a	46.82a	4.62a	5.02a	9.54a	10.22a
H2	22.02a	18.42a	41.36a	45.94a	4.48a	4.93a	9.46a	10.21a
N0T1	21.70a	17.97a	40.67b	45.42b	4.40b	4.82b	9.03c	9.94c
N0T2	22.12a	18.57a	40.83b	45.83b	4.18b	4.72b	9.02c	9.95c
N1T1	22.13a	18.87a	42.00ab	46.50a	4.62a	5.26a	9.54b	10.36b
N1T2	22.10a	18.60a	41.17b	45.17b	4.28b	4.88b	9.44b	10.24b
N2T1	22.38a	18.53a	43.50a	47.67a	4.70a	5.28a	10.06a	10.59a
N2T2	22.38a	18.33a	42.17ab	46.66a	4.48ab	5.00b	9.93ab	10.50a

For a given year LSMEANS within each column of each section followed by the same letter are not significantly different ($p<0.05$). *N0: Without N application; N1: 35 kg N ha^{-1} ; N2: 70 kg N ha^{-1}; H1: 10 cm cutting height; H2: 40 cm cutting height; T1: planting dates of berseem clover coincident with main crop harvest; T2: planting dates of berseem clover 40 days after main crop harvest.

planting date of berseem clover and the main crop cutting height on crud protein in both Cuts and fiber in Cut2 (Table 5). Fresh and dry weight yield decreased with excessive N fertilizer rates and high cutting height. The highest fresh and dry weight pertained to treatment of 35 kg N ha^{-1}, less cutting height and first planting date of berseem clover (Table 5). As shown in Table 5, the increase in fresh and dry weight yield can be related to better adaptation of berseem clover and more N fixation under nitrogen deficit condition, fewer tillers per hill and more light interception in less cutting height (10cm) in early growing season and proper planting date in the first of planting date of berseem clover. Yield reduction in the second planting date can be due to adverse weather condition. Similar findings have been reported previously in berseem clover genotypes due to late planting (Kendel, 2004; Pourtagie et al., 2005). Kreshmer (1964) observed that late planting resulted in non-establishment of seedlings and limitation of growth and development in berseem clover because of cool weather in early growing stage. N fertilizer treatments showed a significant ($P<0.01$) effect on Crud protein content in Cut1. Increasing the N fertilizer rate from 35 to 70 kg ha^{-1} had no effect on crud protein. But, raising the N fertilizer from 0 to 30 kg ha^{-1} increased the crud protein by 1% (Table5). Generally, crud protein of Cut1 was greater than the second cut under all experimental factors. Decreases in crud protein in the second and third cuts have been found by Kendel, (2004) and Pourtaghie et al. (2005). The effect of N fertilizer rates on fiber content was significant in Cut2 ($P<0.01$). Besides, fiber content was affected by the main crop cutting height and planting date of berseem clover in Cut1. The highest fiber content was obtained from treatment of main effect of N0, H1 and T1. In the present study, the content of fiber in Cut2 was generally higher than Cut1. More fiber content in latest Cuts can face with late of growth season with high temperature (Rethwisch et al., 2002; Kendel, 2004). Two fold interactions of planting date of berseem clover and cutting height on fresh and dry weight yield, crud protein and fiber were significant in Cut1 (Table5). All aforementioned traits had the highest value in short cutting height (10cm) under the first planting date of berseem clover. This might be related to increased activity of berseem clover because of less tillering in ratoon crop in 10 cm cutting height (Table5). There were significant effects of two-way interaction of N fertilizer rates and planting date of berseem clover on fresh and dry weight yield in both Cuts, crud protein and fiber in Cut1. In both cuts, the highest fresh

Table 5. Mean comparison of nitrogen (N), berseem clover planting date (T) and cutting height (H) on fresh and dry weight yield, crud protein and fiber of Berseem clover in 2008.

Treatments*	First cutting				Second cutting			
	Fresh weight Kg/ha	Dry weight Kg/ha	Crud protein (%)	Fiber (%)	Fresh weight Kg/ha	Dry weight Kg/ha	Crud protein (%)	Fiber (%)
N0	5152.1b	665.7b	17.95b	21.75a	13924.4b	1751.5b	17.40a	25.93a
N1	5801.6a	751.7a	18.46a	21.71a	16504.4a	2012.7a	17.50a	25.46b
N2	5002.2b	614.9b	18.52a	21.58a	13667.5b	1695.9b	17.67a	24.86b
TI	5767.5a	769.9a	18.48a	22.26a	15792.9a	2098.2a	17.15a	25.63a
T2	5169.8b	635.0b	18.13a	21.11b	14714.6b	1820.8b	17.73a	25.22a
HI	5395.2a	689.5a	18.62a	21.89a	14784.1a	1842.2a	17.61a	25.56a
H2	5245.1b	655.4b	18.15a	21.57b	14613.3b	1797.8b	17.27a	25.29a
N0T1	5250.3c	699.6b	18.02ab	22.43a	14007.1ab	1753.1ab	17.13ab	26.18a
N0T2	5053.9c	631.8c	17.91ab	21.15ab	13841.7ab	1749.7ab	16.15b	25.68a
N1T1	6006.4a	817.9a	18.61a	22.35a	16452.1a	2031.3a	16.81ab	25.58a
N1T2	5596.9b	685.5b	18.28ab	21.00ab	16556.7a	1994.0a	18.19a	25.33a
N2T1	5145.8c	642.3c	18.83a	22.11a	13619.6b	1710.5ab	17.51ab	25.12a
N2T2	4858.5d	587.6d	18.20ab	21.17ab	13715.3	1631.3b	17.83ab	24.63a
T1H1	5463.4a	728.1a	18.72a	22.30a	14766.7a	1850.5a	16.82a	25.41a
T1H2	5471.6a	701.7a	18.16b	22.22a	14619.2a	1717.9b	17.48a	25.84a
T2H1	5020.8b	649.1b	18.53a	20.89b	14801.6a	1833.9a	17.72a	25.17a
T2H2	5318.8b	630.9b	18.14b	21.32b	14607.5a	1807.6a	17.73a	25.27a
N0H1	5067.9b	660.8b	18.01b	21.63a	13970.9b	1795.9b	16.98a	25.73a
N0H2	5236.3b	670.6b	17.93b	21.87a	13877.8b	1707.1c	17.03a	26.13a
N1H1	5958.6a	768.5a	18.65a	21.75a	16618.6a	2016.9a	17.29a	25.38ab
N1H2	5744.7ab	735.0ab	18.17b	21.68a	16390.2ab	2008.3a	17.72a	25.18ab
N2H1	4899.8b	609.3c	18.67a	21.40a	13762.9b	1713.9c	17.54a	24.95b
N2H2	5104.6b	620.6c	18.38a	21.77a	13572.0c	1678.0c	17.79a	24.8b

For a given year LSMEANS within each column of each section followed by the same letter are not significantly different ($p<0.05$).
*N0: Without N application; N1: 35 kg N ha^{-1} ; N2: 70 kg N ha^{-1} ; H1: 10 cm cutting height; H2: 40 cm cutting height; T1: planting dates of berseem clover coincident with main crop harvest; T2: planting dates of berseem clover 40 days after main crop harvest.

and dry weight yield were obtained from 35 kg N ha^{-1} under the first planting date of berseem clover (Table 5). The results are in agreement with those of Gokko et al. (1999) and Rethwisch et al. (2002), in which the effects of N fertilizer rates or planting date of berseem clover had positive relationship with fresh and dry weight yield. Increasing nitrogen fertilizer caused a reduction trend in the biological efficiency of intercropping (Mohsenabadi et al., 2008). The result showed that two-way interactions of N fertilizer rates and main crop harvest height were significant on forage yield in both Cuts, crud protein in Cut1 and fiber in Cut2. Overall, both Cuts, the highest fresh and dry weight yield were found from 35 kg N ha^{-1} and 10cm cutting height (Table 5). The fact that application of 35 kg N ha^{-1} and lower harvest height increased the values of forage yield and this demonstrated the adequate establishment of berseem clover seedlings to produce withstands plants due to low competition between ratoon crop and berseem clover. In Cut1, crud protein increased with increasing N rates under T1. But it was just the reverse in the case of fiber. The increase in crud protein and decrease in fiber due to the increase in nitrogen application have also been reported by other researchers (Sumner et al., 1995; Guretzky et al., 2008; Almodares et al., 2009).

Land Equivalent Ratio (LER)

Effects of N fertilizer rates and main crop cutting height on total LER were significant ($P<0.01$). Results showed that the total LER was unaffected by main effect of planting date of berseem clover and interactions between treatments. Mean comparison of treatments indicated that the total LER (averaged across N fertilizer rate) increased by enhancing the N application from 0 to 35 kg N ha^{-1}. Increasing the N fertilizer rate from 35 to 70 kg ha^{-1} had no effect on the total LER (Table 6). The positive effects of N fertilizer rate on the total LER, as observed in the present study, has also been reported in different crops such as Italian ryegrass mixture with berseem clover(Arevalo et al., 1994), bromegrass mixtures with alfalfa and red clover (Gokko et al., 1999) and corn (*Zea mays* L.) (Mazaheri et al., 2006). Increasing the main crop cutting height can result in reducing the total LER. The total LER in 10 was higher than of 40 cm. With regard to partial LER, small differences were revealed between the two crops. Partial LER of ratoon grain yield and berseem clover dry weight yield showed that berseem clover had high effect on increasing of yield per unit of land area. In this research, increasing the main crop cutting height from 10 to 40 cm resulted in decrease in partial LER in both crops. This increase at 10cm cutting height can be explained by the fact that inter specific competition has been reduced at this treatment. The total LER tested was unaffected by planting dates of berseem clover. Generally, the total LER was higher in T1 than that of other treatments (Table 6). The results obtained in the present study indicate that intercropping system has preference for sole crop. The yield advantage of the intercropping system, reflected in LER value, showed a 34%, 33% and 28% increase under N fertilizer treatments, planting date of berseem clover (T) and harvesting height (H), respectively, compared to the solely two crops. These findings are in accordance with Vasilakoglou and Dhima, (2008) in intercropping of berseem clover in barley, wheat (Szumigalski and Van Acker, 2008), canola and pisum. The results obtained from the two-fold interactions planting of dates of berseem clover and main crop cutting height (TH), two-way interactions N fertilizer rates and planting dates of berseem clover (NT) on total LER were significant. The total LER under the first planting date of berseem clover and

Table 6. Mean comparison of nitrogen (N), berseem clover planting date (T) and cutting height (H) on Land equivalent ratio.

Treatments*	Total LER	LER r	LER bc
N0	1.09c	0.33c	0.76a
N1	1.40a	0.73b	0.67b
N2	1.43a	0.79a	0.64b
TI	1.33a	0.63a	0.70a
T2	1.28a	0.61a	0.67b
HI	1.33a	0.64a	0.69a
H2	1.26b	0.60b	0.66b
T1H1	1.35a	0.64a	0.71a
T1H2	1.29b	0.61ab	0.69b
T2H1	1.29b	0.62a	0.68b
T2H2	1.26c	0.59ab	0.67b
N0T1	1.10d	0.33d	0.77a
N0T2	1.09d	0.33d	0.76a
N1T1	1.43b	0.75b	0.68b
N1T2	1.37c	0.71c	0.66c
N2T1	1.46a	0.82a	0.64d
N2T2	1.41b	0.77b	0.64d

For a given year LSMEANS within each column in each section followed by the same letter are not significantly different ($p<0.05$), *N0: Without N application; N1: 35 kg N ha^{-1}; N2: 70 kg N ha^{-1}; H1: 10 cm cutting height; H2: 40 cm cutting height; T1: planting dates of berseem clover coincident with main crop harvest; T2: planting dates of berseem clover 40 days after main crop harvest. - LER r: Partial LER of ratoon; LER bc : Partial LER of berseem clover

short cutting height (10cm) was the highest. In addition, the highest total LER was found from 70 kg N ha^{-1} and the first planting date of berseem clover (Table 6). Increase in the total LER in this treatment can be due to reduced competition, increased light interception and increased ratoon rice grain yield and forage yield.

Conclusions

Our results here clearly demonstrate that intercropping of berseem clover with rice is possible. The Performance of ratoon rice-berseem clover intercrops was influenced by N fertilizer rate, the main crop cutting height, planting date of berseem clover and environmental conditions. Ratoon rice grain yield was greater under 70 kg N ha^{-1} and 10 cm cutting height. Also, the highest forage yield was obtained from treatment of 35 kg N ha^{-1}, 10 cm cutting height and the first planting date of berseem clover. In the present study, the total LER indicates that intercropping system has greater yield than mono cropping. The competition between two crops was at minimum level. In general, qualitative and quantitative traits of ratoon rice and berseem clover in 2008 were reported to be better than that in 2007. Such an increase may be in the light of favorable weather conditions, improving physical and biological composition of soil and preventing soil degradation. Intercropping berseem clover with ratoon rice has not been done so far, and this would be a challenge for further study on these cases in relation to the present system.

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