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# Evaluation of Barley–Vetch Intercrop at Different Nitrogen Rates

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## ABSTRACT

**To evaluate the yield and quality of barley (*Hordeum vulgare*)–vetch (*Vicia desycarpa*) intercropping, a series of experiments were conducted at the Experimental Field of the College of Agriculture, University of Tehran, in Karaj (Iran) from 2003 to 2005. The experiments were arranged in a randomized complete block with a split plot design and four replications. Three levels (0, 45 and 90 Kg N ha$^{-1}$) of nitrogen fertilizer and three cropping systems (sole barley, sole vetch and barley-vetch intercropping) were allocated to the main and sub plots, respectively. The barley-vetch intercropping treatment had a replacement arrangement (50: 50) with single alternate rows. Land equivalent ratio (LER), was used to compare sole cropping with intercropping systems. Results showed the supremacy of intercropping of barley and vetch over single crops. Generally, increasing nitrogen fertilizer caused a decreasing trend in the biological efficiency of intercropping. The highest LER for grain was obtained in control (N fertilizer free) plots (LER= 1.145). Nitrogen fertilizer increased the forage yield, grain yield, crude protein content, and crude protein yield of barley and vetch in sole and intercrops. Nitrogen application increased water use efficiency. In this study, barley was the dominant crop. The intercropping vetch and barley had the highest productivity and crude protein yield.**

**Keywords:** Barely, Intercropping, Nitrogen, Vetch, WUE.

## INTRODUCTION

Intercropping has been practiced traditionally in tropical regions for centuries. Interest in the intercropping of cereal-legume has been growing in many temperate and tropical regions in recent years (Geno and Geno, 2001; Vandermeer 1992). This is due to the numerous benefits of intercropping of different crops.

Barley/pea intercropping increased the total yield and protein content of the forage compared to sole barley cultivation (Chen *et al.*, 2004). In another study, significant differences in dry matter and crude protein production were observed in different mixture ratios of rice bean and blue panic compared to their pure stands (Parveen *et al.*, 2001). Zhang and Li (2003) in their review reported few examples of inter-specific facilitation, where maize improved iron levels of intercropped peanut, in other experiments faba bean enhanced nitrogen and phosphorus uptake when intercropped with maize and, finally, chickpea facilitated P uptake for its companion wheat. Furthermore, intercropping reduced the nitrate content in the soil

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profile since intercropping used soil nutrients more efficiently than sole cropping.

Stout *et al.* (2001) showed that Persian clover (*Trifolium resupinatum*) is a valuable addition to barley-rye grass mixtures. This crop reduces fertilizer needs and improves forage nutritive value. Legume-grass mixtures not only increases forage yield but also provide nursing and physical support for the companion legume (Soya, 1994). Thus the potential benefits of legume-cereal mixtures over their monocultures might be due to their higher yield, protein and forage quality, yield stability and reduced incidence of pests, weeds, and diseases (Carr *et al.*, 1998). Intercropping of vetch with barley grown for forage and grain may improve forage quality and yield. Many researches have showed that intercrops exhibit greater production than respective sole crops (Hossaini, 2003; Zhang and Li, 2003). Hauggaard and Jensen (2001) in their study on barley (*Hordeum vulgare*)/pea (*Pisum sativum*) intercropping showed that application of nitrogen caused a dynamic change in the intercrop composition. Competition from barley increased with nitrogen application and the pea contribution to the combined intercrop grain yield decreased. The LER values showed in intercrop plant growth resources were used on average 20% more efficiently without nitrogen application and 5-10% more efficiently with nitrogen application. Work done by Banik (1996) on wheat and legumes (pea, lentil and gram) intercropping suggested that the intercropping advantage indicated that a 1:1 replacement series under all treatments was advantageous whereas a 2:1 replacement treatment was not remunerative. Barley (*Hordeum vulgare*) and oat (*Avena sativa*) have been intercropped with field pea (*Pisum sativum*) to increase forage yield and quality by Carr *et al.* (1998). Their results showed that intercropping did not increase forage CP (crude protein) concentration in high-soil-N environments, but it did in low-soil-N environments, which is similar to results reported by other researchers. This suggests that the CP concentration of cereal forage can be increased by intercropping cereals with legume in low-N environments, but the impact of intercropping on forage CP concentration may be negligible when plant growth is not limited by N.

Most studies on intercropping have focused on final yield and have rarely discussed resource utilization (water, light and nutrients). In arid and semi-arid regions, water is the most important limiting factor for crop production. Output improvement in a crop production system is related to the better use of resources. Therefore, understanding the dynamics of resources (especially water) in intercropping systems enhances the development of management strategies to increase the productivity of these systems (Jahansooz, 1998).

The objectives of this research were to compare the possible advantages of intercropping over monoculture regarding: (1) the quality and quantity of forage under different nitrogen levels; (2) the feasibility of intercropping vetch with barley for forage in a short season growing environment; and (3) comparing of water use and water use efficiency in these cropping systems.

## MATERIALS AND METHODS

### Experimental Design

Field experiments were conducted at the Experimental Field of the College of Agriculture, University of Tehran, at Karaj (35 48'N, 51 10'E) in Iran during 2003 -2005.

The long term annual maximum, minimum and mean temperatures were 40, -18 and 13.5 degrees of centigrade, respectively. Annual precipitation is 265 mm and, so, Karaj has an arid Mediterranean climate. Monthly rainfall data for 2003-2004 and 2004-2005 are presented in Figure 1. Total precipitation during the experimental period (2003-2004 and 2004-2005) was 250 and 318.7 mm, respectively.

The soil texture of the research station was clay-loam. Soil tests were conducted in the autumn of the year prior to planting. Phos-

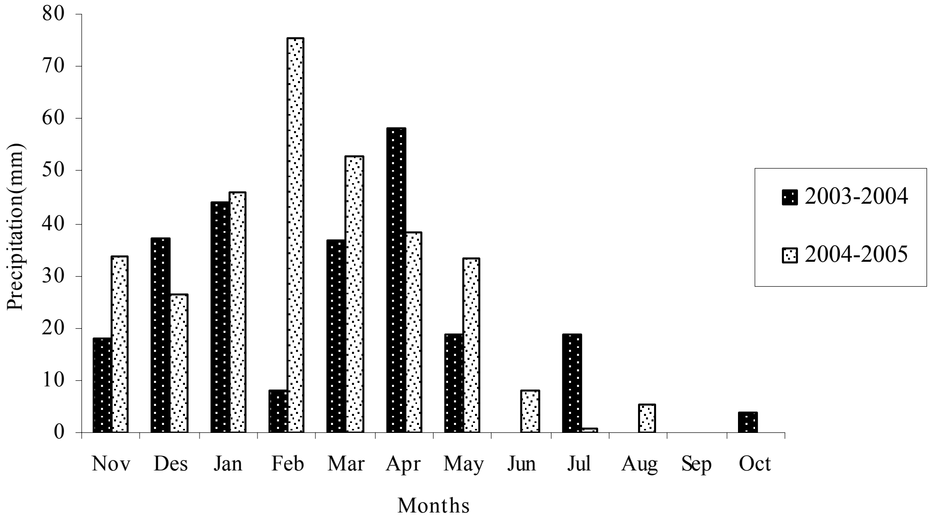

**Figure 1**. Annual precipitation in Karaj, Iran (2003-2005).

phorus and K were fertilized prior to sowing by 130 Kg ha$^{-1}$ of triple super phosphate and 120 Kg ha$^{-1}$ of $K_2O$. Available soil N levels at sowing time (0-30 cm) were 0.06% in first year and 0.09% in the second year. Three levels of nitrogen rate (0, 45 and 90 Kg N ha$^{-1}$) were allocated to the main plots. Granular urea was banded on rows as the nitrogen source. Half of the nitrogen rates were applied at sowing time and the rest was added in spring during the accelerated vegetative growth period. Sole barley (*Hordeum vulgare*), sole vetch (*Vicia desycarpa*) and barley-vetch intercropped treatments were allocated to the sub plots. In the intercropping treatment barley and vetch were planted in single alternate rows. Thus the sowing proportions in intercropping mixtures were 50:50. All crops were hand seeded on the basis of 250 seeds/m$^2$. The crops were planted on 4th November 2003 and 11th November 2004. The area of each plot was 15m$^2$ (3 × 5m) and consisted 12 rows of 0.25m apart. Treatments were arranged in a split plot design based on randomized complete blocks with four replications.

Vetch was inoculated with proper rhizobium species (*Rhizobium leguminosarum* bv. viciae) prior to planting. For inoculation we first made 20% sugar solution and then added this solution to the seeds and, after that, the seeds were inoculated with bacteria. The experimental area was left fallow in the previous year.

## Soil Moisture Measurements

Soil water content and its matrix pressure at field capacity (FC) and permanent wilting point (PWP) were determined (30 and 12 volumetric percent, respectively) through a pressure plate instrument. The soil water budget was measured using a moisture meter (Delta T model 550 British). Polyethylene tubes 1m long and 20mm in diameter were installed at the middle of each experimental plot. The depth of soil was 0.6m and 0.4m of each tube was left above the ground. Volumetric soil moisture was measured at three depths of 0.10, 0.30 and 0.60 m. To prevent water stress, when mean soil moisture content reached 21 percent, irrigation was applied. The amount of irrigation water was 450 litres or 30 mm height per plot at each application (calculations not shown). Four times of irrigation were conducted in the first year where only three times were applied in the second year.

The crop water use or evapotranspiration (ET) was calculated from the changes in the storage of soil water, rainfall and irrigation data using the following equation,

$$\Delta S = (P + I) - (R + D + ET)$$

where $\Delta S$ is the change in soil moisture storage (mm); P= Precipitation (mm); I= Irrigation (mm); R= Runoff (mm); D= Drainage (mm) and ET= Evapotranspiration (mm).

Moisture deficit up to FC was applied to the soil with volumetric counter to compensate for water deficiency. Since the water applied was controlled not to exceed the soil FC, water drainage was very low and almost negligible. Also runoff was eliminated by creating ridges around the experimental plots. As a result the water budget could be calculated by the following equation,

$$\Delta S = P + I - ET$$

so that

$$ET = P+I - \Delta S$$

WUE (kg $ha^{-1}$ $mm^{-1}$) was calculated from below equation,

WUE=DM (dry matter above ground biomass kg $ha^{-1}$)/ET (mm)

Half of each experimental plot area was hand harvested at crop maturity to determine the grain yield and total dry matter production.

Land equivalent ratio (LER), which is defined as the relative land area under sole crop that is required to produce the yields achieved in intercropping, was used to compare cultivar performance in intercropping relative to sole cropping.

Since grain and straw from both vetch and barley were used for feeding livestock, total above ground dry matter was proposed as forage yield. The quality of forage (crude protein) was determined by near infrared spectroscopy (NIR) (Redfearn *et al.*, 1999). Data were analyzed using MSTATC statistical software. All data had a normal distribution. Duncan's multiple range tests was used to compare the means of the treatments.

## RESULTS AND DISCUSSION

The year did not have a significant effect on total forage yield and grain yield (Table 1).

Although there was no significant interaction effect between nitrogen levels and cropping systems, Duncan's multiple range test showed that the means had significant differences ($P \leq 0.05$). Nitrogen fertilizer enhanced biomass and grain production. Application of nitrogen fertilizer significantly increased the biological yield, grain yield, crude protein content and crude protein yield of barley and vetch in sole crops (Table 2).

**Table 1.** Compound analysis of variance table.

| | | Vetch total biomass yield | Vetch grain yield | Barley total biomass yield | Barley grain yield |
|---|---|---|---|---|---|
| S.O.V. | D.F. | M.S. | M.S. | M.S. | M.S. |
| year | 1 | 1103.2 | 292.4 | 18838.9 | 11329.2 |
| R(Y) | 6 | 1417.9 | 547.1 | 20632.7 | 6408.8 |
| Nitrogen | 2 | 21982 $^{*}$ | 790.5 | 67673.8 $^{**}$ | 13406.5$^{*}$ |
| Y*N | 2 | 6058.2 | 1494.2 | 698.9 | 428.2 |
| C.S. | 1 | 1800418 $^{**}$ | 250444 $^{**}$ | 546037 $^{**}$ | 72213$^{**}$ |
| Y*C.S. | 1 | 1871.2 | 1181.7 | 4117.2 | 1939.2 |
| N*C.S. | 2 | 687.9 | 395.7 | 43670.3 $^{*}$ | 8070.9 |
| Y*N*C.S. | 2 | 2082.7 | 607.4 | 1730.1 | 590.7 |
| Error | 30 | 4258.7 | 1129.4 | 11628.7 | 3311.9 |
| C.V. | | 18.9 % | 24.54 % | 13.79 % | 17.06 % |

* Significant at $P<0.05$

** Significant at $P<0.01$

**Table 2**. Biological dry matter yield, grain yield and crude protein content of barley and vetch in sole and intercropping systems (mean of tow years).

| Treatments | Boil. yield (g m-$^{2}$ ) | | Grain yield (g m$^{-2}$ ) | | Crude protein content (%) | | Crude protein yield (g m$^{-2}$) | |
|---|---|---|---|---|---|---|---|---|
| | Barley | vetch | Barley | vetch | Barley | vetch | Barley | vetch |
| Sole cropped | | | | | | | | |
| 0 kg N ha$^{-1}$ | 847.8 b | 499.3 b | 325.5 b | 197.5 a | 17.34 cd | 24.2 b | 147 b | 120.43 b |
| 45 kg N ha$^{-1}$ | 855.9 b | 518.8 ab | 321.3 b | 214.2 a | 17.13 d | 26.8 a | 146.61 b | 139.03 ab |
| 90 kg N ha$^{-1}$ | 1050 a | 632.2 a | 416.5 a | 238.2 a | 18.32 bc | 25.14 b | 192.36 a | 158.93 a |
| Intercropped | | | | | | | | |
| 0 kg N ha$^{-1}$ | 657.2c | 132.8 c | 276.1 b | 57.92 b | 18.38 bc | 20.8 f | 136.69 c | 27.62 c |
| 45 kg N ha$^{-1}$ | 682.7 c | 121.2 c | 288.1 b | 50.26 b | 19.16 ab | 22.78 e | 130.80 c | 27.61 c |
| 90 kg N ha$^{-1}$ | 718.1bc | 196.8 c | 304.5 b | 78.5 b | 20 a | 24.92 c | 143.62 c | 49.04 c |

Different letter in the same column indicate a significant difference ($p<0.05$).

Barley, with, its superior ability to uptake nitrogen and with a more vigorous rooting system, was able to make a more efficient use of the available resources which caused it to become the dominant crop in intercropping treatments. Vetch crude protein content decreased in intercrops compared to vetch in a sole cropping system while the crude protein content of barley in the intercropping system was higher compared to sole barley (Table 2). Chen *et al.* (2004) found that, under low fertility conditions, a 50:50 mixture of barley and pea yielded as well as pure stands of barley. However, when 40 Kg ha$^{-1}$ of nitrogen was applied, the mixture yielded more biomass than the pure stands. At 80 Kg ha$^{-1}$ of N treatment, the barley pure stands and the mixture did better than the pea pure stands. Carr *et al.* (1998) found that N fertilization favored the cereal component at the expense of the pulse in mixed cropping systems.

The results showed that the intercropping of barley and vetch was more productive than sole crop of either species (Table 3). The highest LER was obtained in control plots with no nitrogen application. In general as the nitrogen application rate was increased, the productivity of intercropping followed a decreasing trend. Increased productivity through intercropping has been reported by many researchers (Hauggaard-Nielsen and Jensen, 2001; Qamar *et al.*, 1999; Francis, 1989). This has been attributed to the availability of overall nitrogen, which is not only due to the additional yield of the legume component but also from the productivity of individual plants of the grass component through a better nitrogen supply at the single plant level (Parveen *et al.*, 2001). The other reason could be due to the facilitative effect of vetch, which can uptake part of its nitrogen requirements through symbiotic biological nitrogen fixation which, in turn, reduces the over burden pressure on soil nitrogen supply. Through this process barely will have more available soil nitrogen to utilize. A facilitative production principle is proposed based on several years of studies on intercropping. This means that interspecific interaction increases the growth, nutrient uptake and yield of dominant species, but decreases the growth and nutrient uptake of the subordinate species during the co-existence stage of the two crop species (Zhang and Li 2003).

[ DOR: 20.1001.1.16807073.2008.10.1.3.5 ]

**Table 3.** Lb, Lv and LER of total dry matter yield, grain yield, total protein yield and grain yield protein. (mean of tow years).

| Nitrogen | Boil. yield |  |  | Grain yield |  |  | Protein yield |  |  | Grain protein yield |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Lb[a] | Lv[b] | LER[c] | Lb | Lv | LER | Lb | Lv | LER | Lb | Lv | LER |
| 0(kg.ha$^{-1}$) | 0.776 | 0.268 | 1.045 | 0.842 | 0.302 | 1.145 | 0.800 | 0.242 | 1.043 | 0.323 | 0.824 | 1.148 |
| 45(kg.ha$^{-1}$) | 0.804 | 0.237 | 1.043 | 0.924 | 0.234 | 1.155 | 0.848 | 0.206 | 1.052 | 0.231 | 0.887 | 1.118 |
| 90(kg.ha$^{-1}$) | 0.701 | 0.318 | 1.018 | 0.759 | 0.334 | 1.090 | 0.778 | 0.339 | 1.117 | 0.330 | 0.704 | 1.033 |

[a] Barley yield in intercropping / barley yield in monoculture.
[b] vetch yield in intercropping / vetch yield in monoculture.
[c] Land equivalent ratio.

The forage quality of cereal crops is generally lower than that required to meet production goals for many livestock classes, whereas annual legume-cereal mixtures are important protein and carbohydrate sources for livestock (Carr *et al*., 1998).

The water uptake pattern in intercropped plants was different from that in sole crops. Over the period of the experiment (two years), water uptake was not affected by nitrogen treatments. Water uptake of a crop is dependent on its root capacity and distribution of the root in the soil profile. Crops with a potentially deep root system may produce even deeper roots in intercropping systems (Francis, 1989).

In all treatments the upper layer of the soil surface (0–10cm) was dried because of accelerated evaporation. However, in the lower layers of the soil, because of the lack of evaporation, the amount of the available soil moisture was determined by the ability of roots to uptake the water at those depths (Figure 2). It seems that barley, with its dense and efficient root system, at a 20-30cm soil depth was able to absorb the available water up to the WP. However, water in the lower soil layers was not as efficiently consumed because of the less root density of barely in those depths (Figure 2).

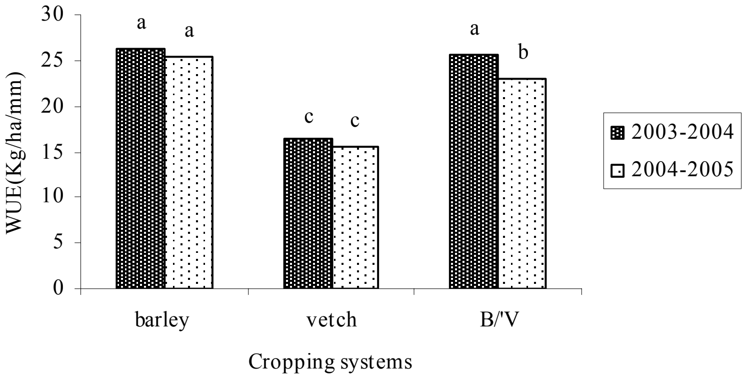

**Figure 3**. Water use efficiency of total forage yield in different cropping systems during 2003-2004 and 2004-2005.

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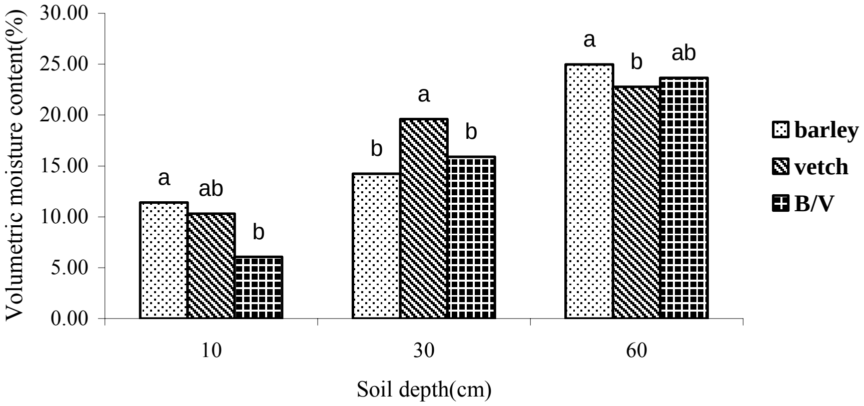

**Figure 2**. Soil moisture of different cropping systems at three depths (mean of two years).

Since vetch is an indeterminate crop, it had a longer growth period than barley. As a result a better and more developed rooting system was created for this crop compared to barley which gave vetch the ability to uptake the moisture from the lower layers of the soil at the end of the season (Figure 2). In the intercropping system, vetch was the recessive crop and tolerated a severe yield loss in competition with barley. The loss of above ground growth led to a negative effect on root development and, as a result, the water uptake ability of vetch in the intercropping system was significantly reduced.

In regards to water consumption in the intercropping system, the competitive production principle plays a key role which explains that in competition for water among different species, rarely one species change the environment in favor of another one and that is why the limitation of moisture in intercropping system could lead to the domination of one crop in expense of damage to the other (Zhang and Li, 2003).

Based on the compound analysis, the effect of the year was not significant on WUE but there was a significant interaction effect between different years and cropping systems ($P \leq 0.05$) on WUE (Figure 3). There was no significant difference between sole barley with the intercropping system in the first year. The results showed that, as nitrogen application increased, WUE followed an increasing trend (Figure 4), this increase in WUE being due to an overall increment of yield and more efficient utilization of unit of water per unit of yield. Sole barley had the highest WUE and sole vetch had lowest the WUE. Intercropping had no significant effect on WUE. But Morris and Garitty (1993) showed that WUE of intercrop was 18–99 % higher than in a sole crop. They concluded that this increment was dependent on the following factors:

1- Lower ratio of ET in favor of evaporation.
2- In intercropping, the canopy was closed earlier.
3- A favorable microclimate was produced under taller plants that increased vapor pressure which resulted in lower transpiration of shorter plants.

In conclusion, the intercrop vetch and barley had the higher productivity and crude protein yield so could be recommended for this region.

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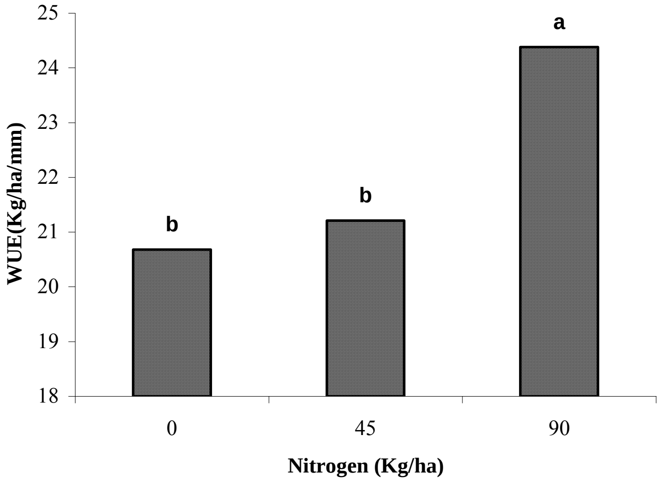

**Figure 4**. Water use efficiency of total forage yield at different nitrogen levels (mean of tow year).

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# ارزیابی کشت مخلوط جو-ماشک در سطوح مختلف کود نیتروژن

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## چکیده

بمنظور ارزیابی کشت مخلوط جو(*Hordeum vulgare*) و ماشک(*Vicia) desycarpa* آزمایشی در مزرعه آموزشی و پژوهشی دانشکده کشاورزی دانشگاه تهران طی سالهای زراعی ۸۳-۸۲ و ۸۴-۸۳ انجام شد. آزمایش به صورت اسپلیت پلات در قالب طرح بلوک های کامل تصادفی در چهار تکرار اجرا گردید. کود نیتروژن به عنوان عامل اصلی در سه سطح (۰، ۴۵ و ۹۰ کیلو گرم نیتروژن خالص در هکتار) و کاشت در سه سطح (تک کشتی جو، تک کشتی ماشک و مخلوط ۵۰:۵۰ جو-ماشک به صورت یک خط در میان) در نظر گرفته شد. کشت مخلوط به روش جایگزینی با نسبت ۱:۱ انجام شد. جهت مقایسه تک کشتی محصولات با مخلوط ازشاخص نسبت برابری زمین استفاده شد. نتایج نشان داد که کشت مخلوط نسبت به تک کشتی جو و ماشک برتری داشت(LER>1). بالا ترین مقدار برابری زمین در تیمار عدم کاربرد نیتروژن حاصل گردید(LER=1/145 ) و با افزایش مقدار کود نیتروژن سودمندی مخلوط کاهش یافت. کاربرد کود نیتروژن باعث افزایش عملکرد کل، عملکرد دانه، محتوای پروتئین خام و عملکرد پروتئین در تک کشتی و مخلوط گردید. علاوه بر این کاربرد کود نیتروژن باعث بهبود کارایی مصرف آب شد. در این مطالعه جو در مقایسه با ماشک با داشتن رشد اولیه سریع و سیستم ریشه ای متراکم و کارآمد با استفاده موثرتر از منابع محیطی(آب و نیتروژن) گیاه غالب بود. بطور کلی در این تحقیق کشت مخلوط نسبت به تک کشتی های جو و ماشک از لحاظ کمی و کیفی برتری نشان داد.