Effect of plant density, nitrogen fertilization rate and furrowing on foraged soybean production

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Abstract: A field experiment was carried out at the research farm, Gorgan University of Agricultural Sciences and Natural Resources, Iran, in 2013. The main objective of the present study was to determine the effect of plant densities, fertilization rates on yield and some morphological characteristics of soybean plant. The other objective of this study was, if pod-packaging phenomena did not happen, studying the morphological characteristics of the plant could be used to identify industrial ways in either a direct feed production or extract oil. Therefore, an experimental design was laid out in a randomized complete block design arranged in a split plot factorial with three replications. The main plots attributed to planting density at three levels (100000, 150000 and 200000 bush ha^{-1}). The sub plots attributed to fertilization rate, Urea 46% at three levels (100, 200 and 300 kg ha^{-1}). The sub-sub plots attributed to land aeration (creating gutter and hillock with furrower) between the rows, during crop protection at two levels (furrowed and non-furrowed only as control). The results showed that with increasing number of plants per plot, dry matter weight and plants height increased to 508.7 kg ha^{-1} and 68.8 cm, respectively. However, stems diameter, number of leaves and number of branches per plant decreased to 5.79 mm, 37.1, and 6.4, respectively. Fertilization rate, furrowing and interaction of plant density × fertilizer rate × furrowing showed that dry matter weight, stems diameter, number of leaves, plants height and number of branches per plant were highest with increasing plant density. The urea fertilizer (46%) and furrowing between the rows indicated that the quantity increase of triple interaction for the afore-mentioned traits were 631.6 kg ha^{-1}, 12 mm, 73, 78.7 cm and 10.33, respectively. Overall, findings demonstrated that using fertilizer and furrowing between the foraged soybeans rows may create more bushes efficient via absorption of urea followed by furrowing. Therefore, it caused the greater morphological yield.

Keywords: fertilizer, furrower, soybean (*Glycin Max*), seeding rate

Citation: Shamsabadi, H., D. Ahmad, and A. Saberi. 2017. Effect of plant density, nitrogen fertilization rate and furrowing on foraged soybean production. Agricultural Engineering International: CIGR Journal, 19(3): 32–38.

1 Introduction

Soybean (*Glycine max (L.) Merrill*) is a unique forage crop, because it not only produces quality forage, but also is an energy and protein dense bean that can be consumed by grazing animals. This leads to the issue of combining the stem with the silage, feed refusal, and an ultimate waste of the high-protein, high-energy bean (Blount et al., 2009). As soybean oil, prices began to soar in 1960's, its value as an oilseed and protein crop far outweighed as forage. Though soybeans are now cultivated almost exclusively as a high protein or oilseed crop, however their value as forage is being reconsidered, and even implemented in certain parts of the world. So, why a farmer wants soybean for a forage?

The other major factor affecting soybean forage yield is row spacing. All of the extension-reviewed papers recommended smaller row spacing. An investigation in

Received date: 2016-12-06 **Accepted date:** 2017-02-06

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Turkey revealed that the narrowest row spacing, regardless of number of planted seeds, resulted in a higher percentage of plants reaching maturity, 68.3% at 20 cm and 54.4%, 48.5%, and 44.8% with increasing rate of 40, 60 and 80 cm, respectively (Acikgoz et al., 2009). This is in agreement with previous work that demonstrated the narrow-row spacing and seeding rates of 240,000 to 315,000 seeds ha^{-1}, or greater provides the greatest soybean yield with density reduction (Schultz et al., 2015).

Yield of soybean in other research compensated in seeds plant^{-1} at lower seeding rates than those obtained from wide rows resulted in seed densities (2123 to 2234 seeds m^{-2}) across seeding rates. Nevertheless, yield showed a quadratic response to seeding rate (3.04, 3.25, and 3.12 Mg ha^{-1} at 321,000, 420,000, and 469,000 seeds ha^{-1}, respectively) with no row spacing interaction (Cox and Cherney, 2011). Moreover, the same result observed in Maturity Group III Soybean (MG III) product (Walker et al., 2010). They illustrated that narrow row spacing generally produced yields greater than at wider rows. This type of cultivation, narrow row spacing, resulted in a final population of 300,000 plants ha^{-1} to provide optimum yields. In general, row spacing shown to finding in higher yields.

Beyond agronomy and economics standpoints, soybeans provide a number of ecological benefits as well. They produce nitrogen through their symbiosis with Rhizobium, provide an excellent wildlife fodder to encourage on-farm biodiversity, and give the producer an opportunity to double crop and keep soil covered after a cereal crop harvested in early summer. In general, adapted varieties of soybean provide high quality forage for grazing animals during the hottest months of the year. Silage or hay Soybean is on par with alfalfa. With affordable seed costs, foraged soybean is a real opportunity for beef cattle producers everywhere.

One of the most important operations in the crop protection period is applying of furrow (furrowing) between the rows, while many of farmers do not know about its advantages. In fact, when furrower is applied, it is accomplishing with the advantages of crust layer breaking, weed ruining, breaking capillary tube, soil aeration, intensification of soil micro-organisms activity, soil moisture content control, development and or increase in soil moisture content and nutrition with rival elimination (weeds), increase in absorption ability of nutrients by the plants. The afore-mentioned advantages are influence on the vegetative and reproductive growths of crops.

Therefore, regarding to the afore-mentioned advantages of soybean, the present study was carried out with the main objective of finding the influence of plant density, fertilization rate and applying the furrower among the rows of crop during crop protection on dry matter weight and morphological traits of foraged soybean. The specific objectives were to find interaction effects of plant density × fertilization rate, plant density × furrowing and non-furrowing, fertilization rate × furrowing and non-furrowing and fertilization rate × plant density × furrowing and non-furrowing on the measured traits of foraged soybean.

2 Materials and Methods

2.1 Experimental site

The field experiment was conducted at the research farm of Gorgan University of Agricultural Sciences and Natural Resources, (30 km east south of Caspian Sea), Iran, in 2013. The afore-mentioned farm was under wheat-soybean rotation. Geographical coordinates of the farm were 36°, 54.00′ N, 54°, 25.00′ E and altitude of 51 m. The 25-year mean temperature, humidity and precipitation recorded were 17.7°C, 70% and 617 mm, respectively. Table 1 shows some soil analysis of the farm. The selected field was under wheat rotation, after harvesting wheat on 15 June of 2013.

Table 1 Some soil characteristics of the experimental site

CEC, Cmol kg^{-1}	EC, ds m^{-1}	OM, %	pH	Soil texture	Sand, %	Silt, %	Clay, %
20.60	0.88	1.8	8.2	silty- clay loam	18	46	36

2.2 Implements

A tractor for land preparation was a MF285 with a maximum engine power of 65 HP. The two tillage implements for land preparation were: 1) moldboard plough, mounted type, three bottoms (MP) with the depth of 25 cm and ground speed of 6 km h^{-1} and 2) pull type of a tandem disc harrow with 36 discs (DH) followed by MP, adjusted for the depth of 10 cm and forward speed of 8 km h^{-1}. Working depths of the afore-mentioned implements and their ground speeds chosen based on the common depth and ground speed for each implement. After irrigation and again one time tandem disc harrowing; seeding practice carried out manually based on the number of seed per ha or per m^2, accordance with the layout of the research. Furrowing between the rows carried out by a mounted furrower with four shanks and spacing of 50 cm. It utilized in the indicated plots during crop protection (when the plant height was at about 30 cm).

2.3 Experimental design

Factorial treatments arranged in a randomized complete block design with three replications. The main plots attributed to the three plant densities included of 100000 (D1), 150000 (D2) only as control and 200000 (D3) bush ha^{-1}, with planting pattern of 50 × 20 cm, 50 × 13.5 cm and 50 × 10 cm, respectively. The sub plots attributed to the three fertilization rates (Urea 46%) of 100 (F1), 200 (F2) and 300 (F3) kg ha^{-1}, before furrowing and manually. The sub-sub plots attributed to land aeration between the rows or creating gutter and hillock carried out with a furrower, during crop protection, furrowed (P2) and non-furrowed (P1) only as control. Analysis of variance for the data and the means comparison carried out using the statistical software version 8.2, developed by SAS Institute.

2.4 Measurements

Each plot consisted of four planting rows with the length of 6 m and 50 cm wide. The phenotypic data collected from the two middle rows. The studied traits in legume included: dry matter weight, plant height, and stem diameter, number of plants, number of leaves and number of branches per plant. Sufficient numbers of soybean seed sown manually for each treatment to facilitate destructive sampling for determining relative growth rates at the various growth stages.

3 Results and Discussion

Analysis of variance of the recorded data on dry yield and some agronomic characteristics of foraged soybean showed significant effects between plant density, fertilization rate, furrowing between soybean rows and interaction of this treat (Table 2). Means comparison for dry matter weight, stem diameter, number of leaf, plant height and number of branch of soybean at different plant density demonstrated that with increasing number of plants per plot (91.5), dry matter weight and plant height increased to 508.7 kg ha^{-1} and 68.8 cm, respectively. Whilst, stem diameter, number of leaf and number of branch decreased to 5.79 mm, 37.1, and 6.4, respectively (Table 3).

Maximizing fertilizer consumption on soybean led to greater dry matter weight of 415.6 kg ha^{-1}, stem diameter of 8.81 mm, number of leaf of 56.7, plant height of 61.7 cm and number of branch of 8.27. Furrowing between soybean rows caused aeration, breaking crust layer, ruining of weeds, breaking capillary tubes, intensification soil microorganisms' activity, extension of soil moisture and nutrients with omitting weeds. Consequently, it led to improvements on dry matter weight to 394.7 kg ha^{-1}, stem diameter to 2.76 cm, number of leaf to 8.57, plant height to 58.1 cm and number of branch of soybean to 8.29 (Table 3). The afore-mentioned results were in agreement with other report (Shamsabadi et al., 2015).

Nutritional quality is very important as optimum yield. This is especially true for the economic side of the equation. Like all crops, yield and yield components of foraged soybean affected by planting density, fertilization rate and furrowing. When all of these variables are controlled, however soybean forage yield will follow the same trend with fiber and crude protein and will increase with plant maturity (Sheaffer et al., 2001; Seiter et al., 2004; Bilgili et al., 2006).

A general assumption is that the legume when associated with the specific Rhizobium may have most of its N need supplied through fixation of atmospheric N, leaving the soil available N for the companion crop and nodule decomposition (Adeyeye et al., 2014; Qiao et al., 2014).

There is marked variation in the N supplying ability among legume species. The presence of nodules in inoculated soybean plants well established, as their number affected by the nitrogen fertilizer level. Finding of a research in 2016 demonstrated that by the enhancement of nitrogen rate, the number of nodules and their dry weight per plant reduced (Ahmed, 2016). Moreover, fertilized plants significantly improved seed yield in comparison to non-fertilized plants by 83% and 89%, respectively. Nevertheless, the high nitrogen fertilizer dose (80 kg ha^{-1}) declined the positive effect of inoculum on seed yield. Therefore, they suggested that low level of Application of small N-fertilizer (40 kg ha^{-1}) in combination with rhizobial inoculation seemed to be an appropriate cultivation practice for soybean production.

Table 2 Analysis of variance for dry matter yield and some morphological traits of soybean as affected by planting density, fertilization rate and furrowing

Source of variation	Degree of freedom	Mean Square					
		Number of plants per plot	Dry matter weight	Stem diameter	Number of leaf	Plant height	Number of branch
Replication (R)	2	10.67	352.4	0.645	5.57	4.74	0.167
Density (D)	2	6464.67**	308830.4**	124.58**	4831.68**	2559.29**	53.39**
Fertilization (F)	2	85.06*	24383.7**	2.2802**	420.685**	268.296**	4.667**
Furrow (P)	1	7.41^{ns}	13569.2**	0.9335^{ns}	39.185**	38.170**	0.907^{ns}
D × F	4	37.89^{ns}	2126.4^{ns}	2.0091**	14.380**	39.468**	1.306^{ns}
D × P	2	2.29^{ns}	4450.6*	1.4457*	12.574*	18.636**	0.685^{ns}
F × P	2	3.69^{ns}	1447.2^{ns}	0.3102^{ns}	2.463^{ns}	9.725*	0.074^{ns}
D × F × P	4	10.91^{ns}	3573.0*	0.7791^{ns}	2.269^{ns}	10.475*	0.768^{ns}
Error	34	17.96	954.7	0.3431	2.437	2.736	0.598
CV (%)	-	22.85	31.35	27.32	27.18	18.36	20.43

Note: **, * and ^{ns} are significant at 0.01, 0.05 level and not significant, respectively.

Table 3 Means comparison of dry yield and some morphologic characteristics of soybean at different levels of plant density, fertilization rate and furrowing

Treatment	Number of plants/plot	Dry matter weight, kg ha^{-1}	Stem diameter, mm	Number of leaves	Plant height, cm	Number of branches
			Density			
D1	54.222^{c}	246.833^{c}	11.056^{a}	69.722^{a}	45.056^{c}	9.889^{a}
D2	67.222^{b}	381.056^{b}	8.489^{b}	50.222^{b}	58.111^{b}	8.167^{b}
D3	91.556^{a}	508.778^{a}	5.794c	37.167^{c}	68.868^{a}	6.444^{c}
			Fertilizer			
F1	69.556^{b}	342.056^{c}	8.100^{b}	47.167^{c}	54.722^{b}	7.611^{b}
F2	69.944^{b}	378.944^{b}	8.428^{ab}	53.222^{b}	55.533^{b}	8.611^{a}
F3	73.500^{a}	415.667^{a}	8.811^{a}	56.722^{a}	61.778^{a}	8.278^{a}
			Furrow			
P1	71.370^{a}	363.037^{b}	8.315^{a}	51.518^{b}	56.504^{b}	8.037 a
P2	70.630^{a}	394.741^{a}	8.578^{a}	53.222^{a}	58.185^{a}	8.296 a

Note: Means within columns followed by the same letters are not significantly different at 5% level.
D = Density, D1= 100000 Plant ha^{-1}, D2 = 150000 Plant ha^{-1}, D3 = 200000 Plant ha^{-1}, F= Fertilization rate, F1=100 kg ha^{-1}, F2= 200 kg ha^{-1}, F3= 300 kg ha^{-1} Urea, P1= non-furrowed and P2= furrowed.

Previous research in 2015 reported the same results that the positive effect of N fixation (Ndfa) on crops yield (Collino et al., 2015). The greatest percentage of N fixation demonstrated in areas with high crops yields. The highest of seed yield (more than 3.7 Mg ha^{-1}) and lower than this value improved during fallow and mean temperature in the seed-filling period explained % Ndfa and effective rainfall in the vegetative period explicated % Ndfa.

Competition between component crops for growth-limiting factors regulated by morpho-physiological differences and agronomic factors such as the proportion of crops in the fertilizer application (Ahmed, 2016). Intra specific competition seems to be more intense than inter-specific competition (Oljaca et al., 2000).

Interaction effect of Fertilization rate × Furrowing

(F × P) was significant on Plant height (P<0.05), as observed in Table 2. The lowest and the highest values of the afore-mentioned traits attributed to D1P1 (53.7 cm) and D3P2 (63.2 cm), respectively, with increasing of 17% (Figure 1).

Interaction effect of Density × Furrowing (D × P) on Dry matter weight, Stem diameter and Number of leaf showed significant difference at 0.05 level and on Plant height at 0.01 level (Table 2). The lowest and the highest values of the afore-mentioned traits attributed to D1P1 and D3P2, respectively (Figures 2, 3, 4 and 5). In this regards, quantity increases were 112%, 90%, 90% and 60%, respectively. It could be due to applying the furrower between the rows. Because created sufficient condition on the land/soil for vegetative and reproductive growths of soybean.

As shown in Figures 9 and 10, the triple interaction of plant density × fertilization rate × furrowing on plant height and dry matter weight improved with increasing plant density, urea fertilizer and furrowing between soybean rows (P<0.05). The quantitative increases were 78.7 cm (90%) and 631.6 kg ha^{-1} (325%), respectively.

Interaction effect of Density × Fertilization rate (D × F) on plant height, number of leaves and Stem diameter showed significant difference (P<0.01), as shown in Table 2. The lowest and the highest values attributed to D1F1 and D3F3, respectively. Meaning that with increasing plant population/density and fertilizer consumption; plant height, number of leaf and stem diameter increased too (Figures 6, 7 and 8).

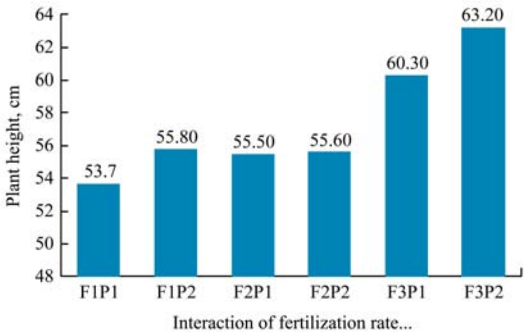

Figure 1 Interaction effect of fertilization rate and furrowing on plant height

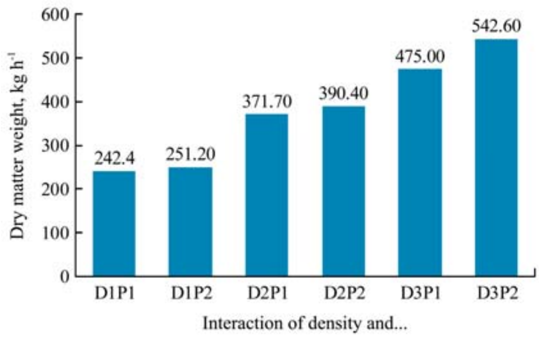

Figure 2 Interaction effect of density and furrowing on dry matter weight

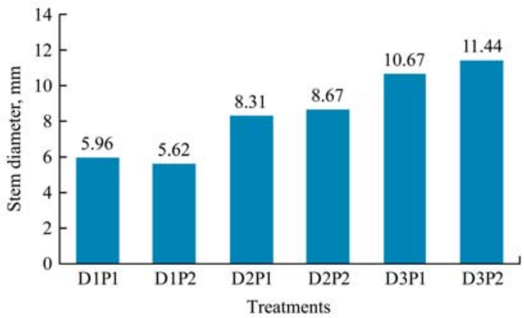

Figure 3 Interaction effect of density and furrowing on stem diameter

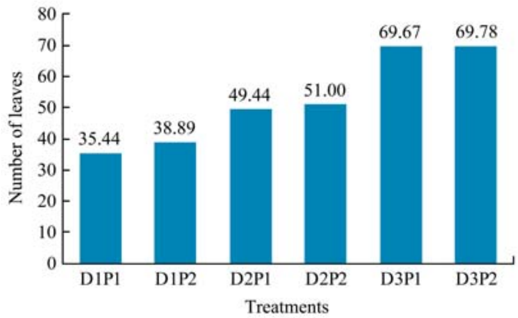

Figure 4 Interaction effect of density and furrowing on plant height

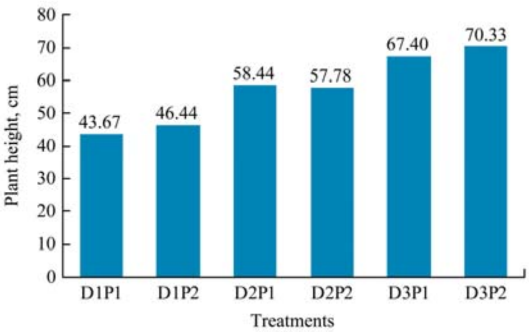

Figure 5 Interaction effect of density and furrowing on plant height

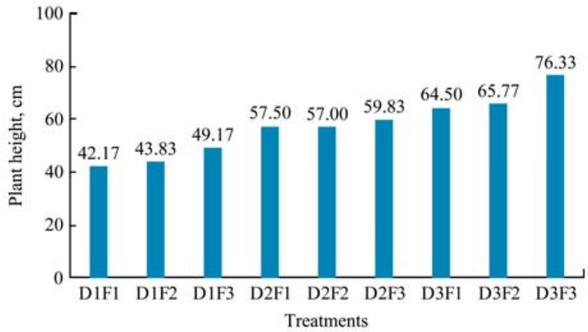

Figure 6 Interaction effect of density and fertilization rate on plant height

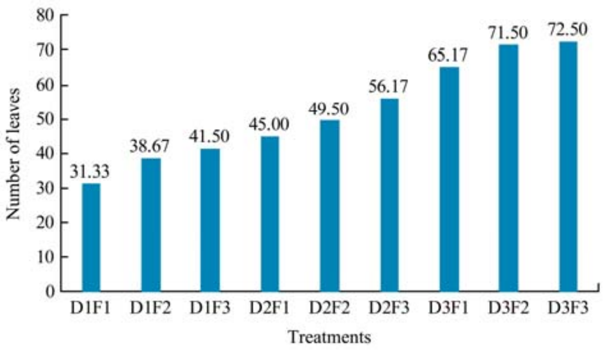

Figure 7 Interaction effect of density and fertilization rate on number of leaves

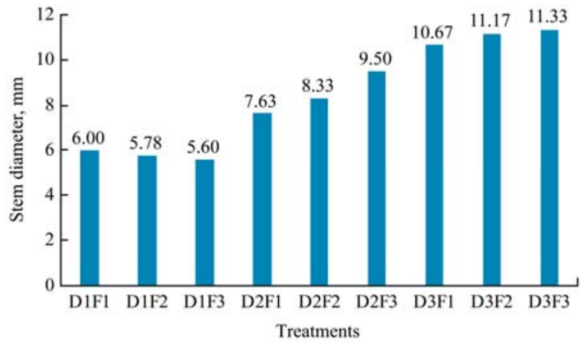

Figure 8 Interaction effect of density and fertilization rate on stem diameter

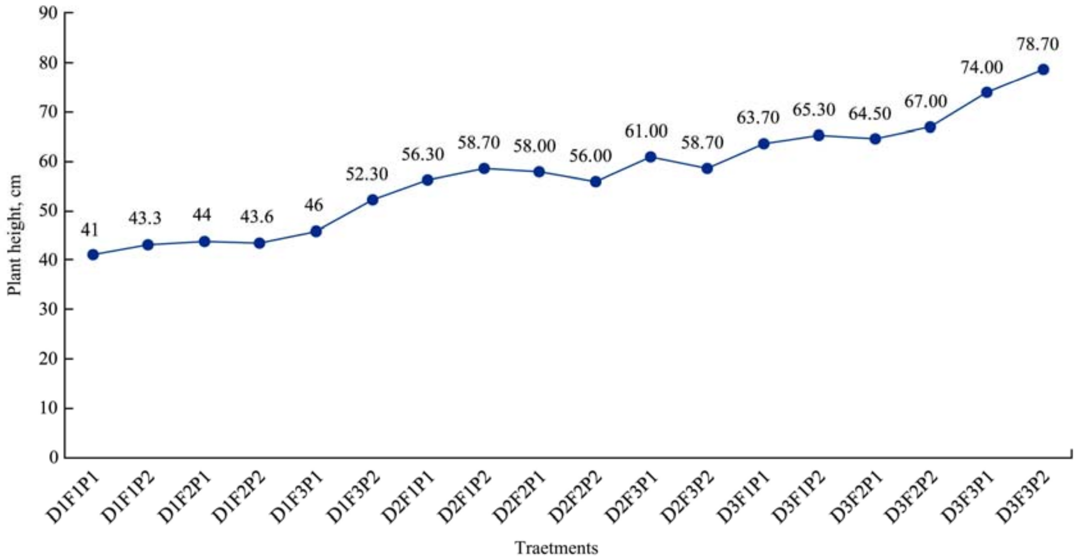

Figure 9 Interaction effect of triple factors (density, furrower and fertilization rate) on plant height

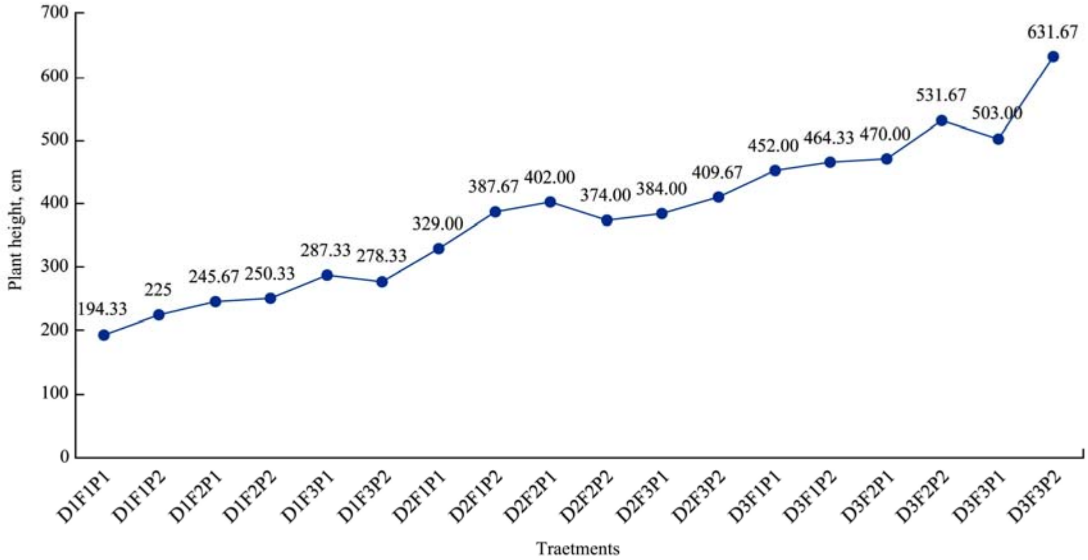

Figure 10 Interaction effect of triple factors (density, furrower and fertilization rate) on dry matter weight

4 Conclusions

The results showed that with increasing number of plants per plot, dry matter weight and plant height increased to 508.7 kg ha^{-1} and 68.8 cm, respectively. Stem diameter, number of leaf and number of branch decreased to 5.79 mm, 37.1, and 6.4, respectively. Fertilizer consumption, furrowing and interaction of them on the measured traits showed dry matter weight, stem diameter, number of leaf, plant height and number of branch were highest in front of increasing plant density, urea and furrowing between soybean rows. For all the afore-mentioned traits, quantitative increase for triple interactions were 631.6 kg ha^{-1}, 4.16 cm, 12 mm, 72, 78 cm and 10.33, respectively. Overall findings demonstrated using fertilizer and furrowing between forage soybeans rows may allow more efficient bushes to urea absorption followed aeration caused to greater morphological parameters and performance yields.

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