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Meta-analysis the effect of nitrogen fertilizer on quantitative and qualitative characteristics of sugar beet

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ABSTRACT: Estimation of the optimum fertilizer for consumption to reduce production costs and environmental risks and yield increase is necessary. Considering the scattering and difference in the results of various experiments, it is difficult to reach a general conclusion. In this study, meta-analysis approach was used to overcome this problem and with aim of integrating and reanalyzing of the results of independent experiments as well as achieving the same result. Hence, 14 research projects, conducted on the effects of nitrogen fertilizer on sugar beet yield during 2002-2013 at research station of sugar beet seed institute by Iranian researchers, were evaluated. The levels of nitrogen used in the studies were 0, 50, 100, 150, 200, 250 and 300 kg N ha-1. Results showed that all traits studied were influenced by N levels. The maximum root yield was related to 300 kg N ha^{-1}. Application of 50-100 kg N ha^{-1} increased sugar content 0.89-0.98% compared to control. Results also indicated that the optimum N required for increasing sugar yield was found to be at the range of 50 to 100 kgha^{-1}.

Key words: sugar beet, meta-analysis, nitrogen.

INTRODUCTION

The increase in population growth has led to higher demand for food crops and plants' dependency on nitrogen. Projections indicate that global fertilizer consumption will be more than 206 million tons by 2020 with more than66% and 53% of demand for developing countries and Asia (Fao 2010). The optimization of nitrogen fertilizer consumption in sugar beet is critical because nitrogen is one of the most important elements required in sugar beet production used in larger quantities than any other mineral nutrient (Weeden 2000).The rate and application how of nitrogen affect on the quality and quantity of sugar beet (Hills *et al.* 1978), so that a higher uptake of nitrogen from the soil increases the roots impurities and thereby reduces recoverable sugar (Cattenach *et al.,* 1993).

Among the impurity components, sodium, potassium, and amino- nitrogen have obtained the most attention in breeding and agronomic programs of sugar beet, because higher concentrations of sodium and potassium and amino-nitrogen in the root lead to a decrease in sucrose concentration. On the other hand, sucrose concentration and thereby recoverable sugar per ton has a great importance to calculate payments to growers (Campbell, 2005; Hoffman et al., 2011). Talleghani (1998) studied water and nitrogen use efficiency in sugar beet production, in Karaj Iran, and found that application of 240 kg N ha^{-1} had the best performance to achieve maximum yield of sugar beet.

According to Glass (1976), meta-analysis is an approach to integrating the findings in which the data of individual researches are analyzed and summarized. In the meta-analysis approach, researcher records the findings and features of a large collection of the researches in quantitative concepts and prepares them for the statistical methods. The basic and practical principle of this approach is combining the different findings and deriving the new and coherent results with deleting the bias and remove what is (Wolf 1986). Based on the Fischer method, the significance level of all research data was determined using Chi-square test.

The benefits of meta-analysis are; 1. apply strong quantitative methods to summarize the long history of research on specific topics, 2. accuracy and objectivity in the study, resulting in a lower likelihood of bias and prejudice and personal judgment of the researcher, and ultimately increase the likelihood of obtaining an accurate results, 3. meta-analysis is a cost-benefit evaluation, and fill in the gaps between previous studies and provides new insights for further research on the topic, 4. meta-analysis does not eliminate weak or non-logical studies, but it compares and adjusts them with other studies (Wachter and Straf, 1990).The meta-analysis by the purpose of integrating the results of previous research follows two main processes; a) In addition to summarizing and describing the results of existing studies in the literature on a certain topic, meta-analysis evaluates the relationship and actual differences in the studies, b) meta-analysis estimates the impact of methodological characteristics of the studies on the difference amount or estimated relationships in the various research on a given topic.

Bilbao *et al.* (2004) evaluated 33 experiments done in different locations between 1989 and 2000 in which the rates of N were 0, 40, 80, 120, 160, 200, 240 and 300 kg N ha^{-1} to estimate optimum N rate for sugar beet (*Beta vulgaris* L.). The results showed that the optimum N rate for adjusted beet production was 268 kg N ha^{-1}.
Hoffman *et al.* (2009) root yield and quality of 9 sugar beet genotypes were investigated in 52 environments and reported that amino N value in environments with low rate of N at was lower than that of in environments with high rate of N and it was increased considerably with the level. Carter (1982) found that although decrease in pure and impure sugar content, sugar beet root yield was increased with increasing N level. Armstrong *et al.* (1986) reported that higher rates of N increased tuber yield, n uptake by plant and root dry mater percentage.
Koochaki *et al.* (2014) reviewed the data from 46 environments conducted on the impact of nitrogen fertilizers on grains yield and concluded that the average yield of wheat, maize and rice increased by 2477, 4699 and 1509 kg ha^{-1} than control, respectively. They also reported that the maximum grain yield and dry matter was produced at 50-100 kg N ha^{-1} and 100-150 kg N ha^{-1} treatments, respectively.

MATERIAL AND METHOD

The study was established at the research station sugar beet seed institute, Karaj, Iran (35°50' N, 50°58' E, and 1313 m). Fourteen studies carried out from 202-2013 by Iranian researchers on the effects of different levels of N fertilizer on quantitative and qualitative characteristics of sugar beet were evaluated.
The information regarding the conducted research including research topic, Location and duration of research, type of experimental design, the number and type of treatments, types and levels of nitrogen fertilizer, the results of research and the effects of nitrogen levels on quantitative and qualitative traits of sugar beet was collected and analyzed.
The levels of nitrogen levels used in the studies were 0, 50, 100, 150, 200, 250 and 300 kg N ha^{-1}. Many different levels of nitrogen fertilizer treatments in the studied research were separately evaluated for each of the levels (Table 1).

Table 1: Distribution levels of nitrogen fertilizer used in testing.

	0	50	100	150	200	250	300
Root Yield	14	11	11	14	9	9	5
Sugar Content	13	11	11	14	9	9	5
K(Potassium)	13	11	10	13	8	8	5
Na(Sodium)	14	11	10	12	8	8	5
α-N(Amino-Nitrogen)	13	11	10	13	8	7	5
Molasses Sugar(MS)	14	11	10	13	8	8	5
Alkalinity coefficient	13	9	9	11	8	8	5
White sugar yield	14	11	11	13	8	8	5

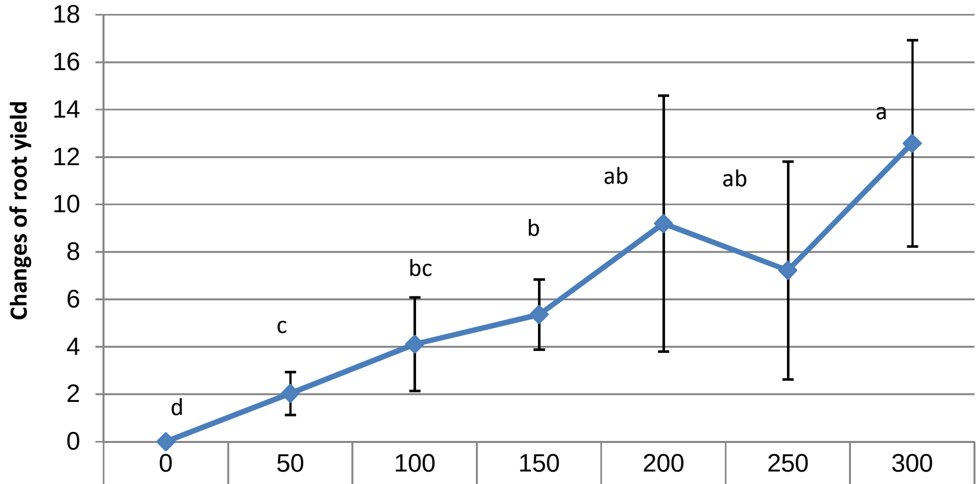
Meta-analysis the effect of nitrogen fertilizer on root yield, extractable sugar yield, sugar content, sodium, and potassium percentage, amino nitrogen percentage, molasses sugar percentage and alkalinity coefficient was estimated. All calculation and charts drawing was done in Excel environment.

RESULTS

A. Root yield
In reviewing the literature, a positive correlation was found between N application and sugar beet root yield. Root yield was increased with increasing N application, so that the maximum yield was found at 300 Kg N ha^{-1} treatment (12.58% compared to control) (Fig. 1). Sugar beet root yield varied from 65.33 t /ha under control treatment to 73.56 t/ ha at 300 Kg N ha^{-1} treatment.

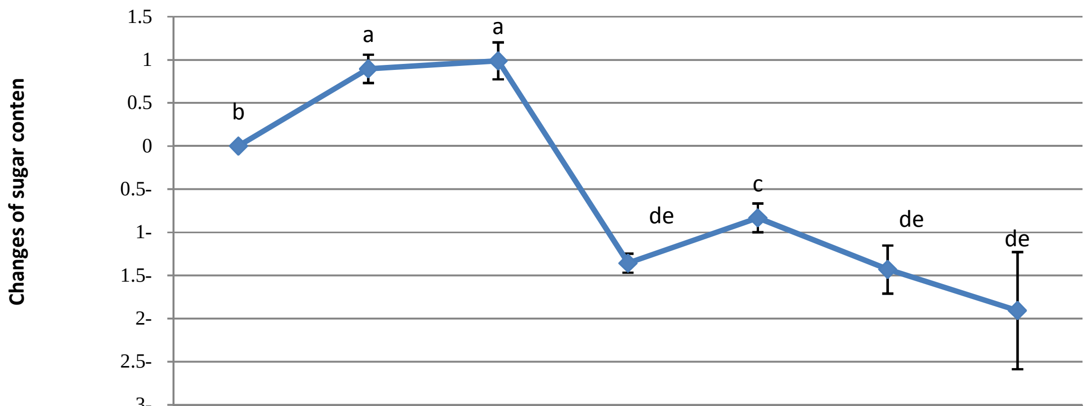
B. Sugar content
Meta-analysis of data indicated that the effect of N levels on sugar content was significant, so that sugar content was increased following the increase of N level and then it was decreased. The maximum and minimum decrease in sugar content was found at 300 Kg N ha^{-1} and 150 Kg N ha^{-1} treatments, respectively (a 9/1-% and 35/1-% decreases compared to control, respectively). Results of meta-analysis also revealed that sugar content improved at 50 and 100 Kg N ha^{-1} treatments, a 0.89% and 0.98% increases compared to control, respectively (Fig. 2). The sugar content was different from 30% decrease at 300 Kg N ha^{-1} to 4.5% increase at 50 Kg N ha^{-1} than control. Together, sugar content varied from 12.45% to 16.86% in various researches.

C. Root Na content
From the data of conducted experiments it was concluded that the effect of N levels on root Na content was significant, so that Na content was increased by N application. The highest and lowest increasing in Na content compared to control (51.98% and 3.4%, respectively) was obtained under 250 Kg N ha^{-1} and 300 Kg N ha^{-1}, respectively, (Fig. 3). In contrast, root Na content varied from a 59% increase at 250 Kg N ha^{-1} treatment to a 1.32% decrease under 300 Kg N ha^{-1} treatment.



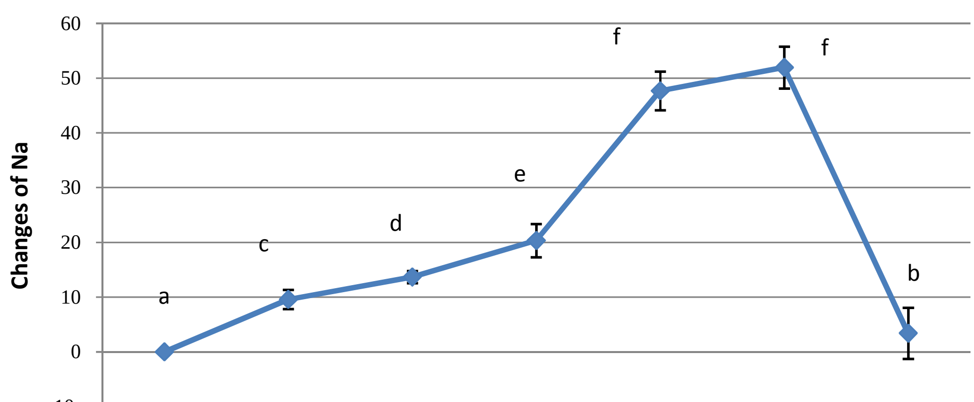
	0	50	100	150	200	250	300
میانگین	0	2.036	4.11	5.36	9.2	7.224	12.58

Fig. 1. Meta-analysis of the percent changes of Root yield.



	0	50	100	150	200	250	300
%	0	0.895774543	0.987672657	1.35897816-	0.83358087-	1.43175404-	1.90851032-

Fig. 2. Meta-analysis of the percent changes of Sugar content.



	0	50	100	150	200	250	300
	0	9.575	13.686	20.3525	47.70666667	51.985	3.403333333

Fig. 3. Meta-analysis of the percent changes of Sugar content.

D. Root K content

According to the data collected, N levels had significant effect on the root K content. Root K content increased with increasing N levels. Here, the maximum and minimum increase in root K content than control was related to 250 and 150 Kg N ha^{-1}, respectively. Results also demonstrated that root K content was decreased at 50 Kg N ha^{-1} (Fig. 4).

E. Aminonitrogen (α-N)

Analysis of data from14 studies conducted showed that the effect of N levels on % of amino nitrogen was significant. Amino nitrogen percentage increased with increasing N levels. The highest and lowest increase in amino nitrogen was observed under 250 Kg N ha^{-1} and 50 Kg N ha^{-1}(Fig. 5).

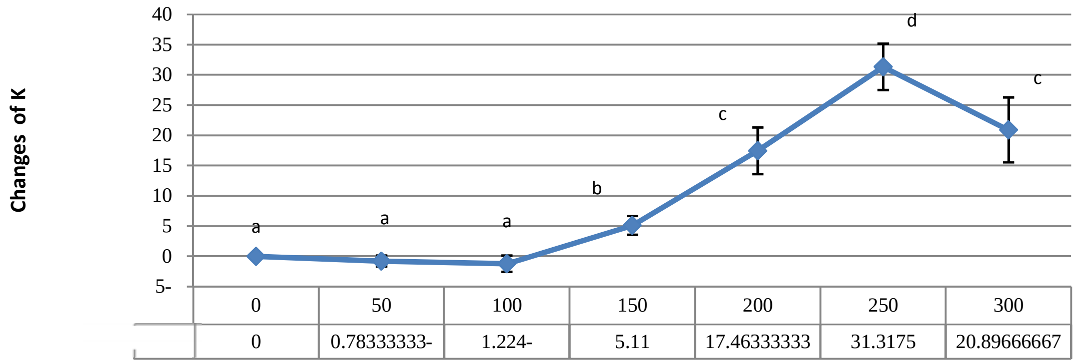


Fig. 4. Meta-analysis of the percent changes of potassium (K).

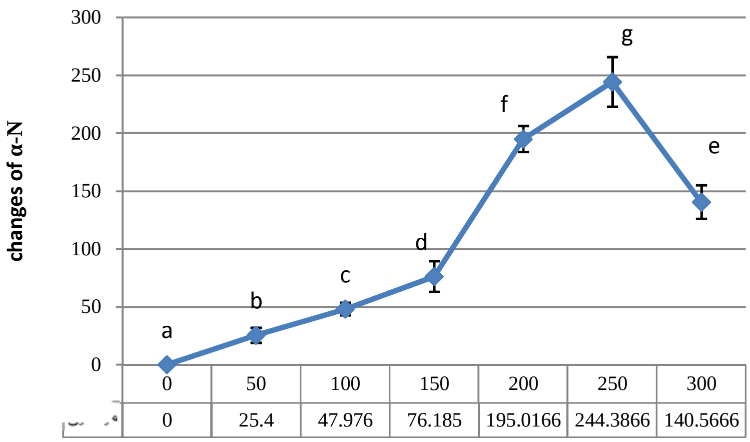


Fig. 5. Meta-analysis of the percent changes of Amino-nitrogen (α-N).

F. Molasses sugar content (MS)

According to the data collected, molasses sugar content was affected by different levels of N, so that increasing the N levels increased the percentage of molasses sugar. Here, the highest and lowest molasses sugar was obtained under 250 Kg N ha^{-1} and 50 Kg N ha^{-1} (Fig. 6). Increasing the N levels beyond 250 Kg N ha^{-1} resulted in decrease in molasses sugar.

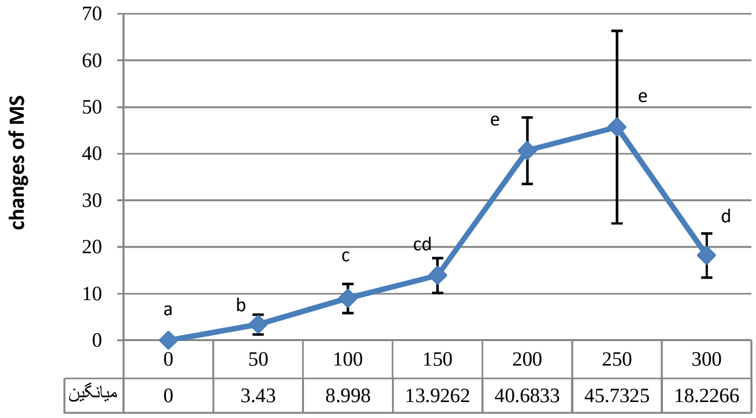
G. Alkalinity coefficient (ALC)

Analysis of data from14studiesconductedshowed that the effect of N levels on % of root alkalinity coefficient was significant. Application of N fertilizer by 200 kg ha^{-1} decreased the percentage of root alkalinity coefficient but higher rates of N led to an increase in root alkalinity coefficient.

The maximum root alkalinity coefficient reduction was related to 200 kg N ha^{-1} application, while the minimum root alkalinity coefficient reduction was related to 50 and 300 kg N ha^{-1} application treatments (Fig. 4).

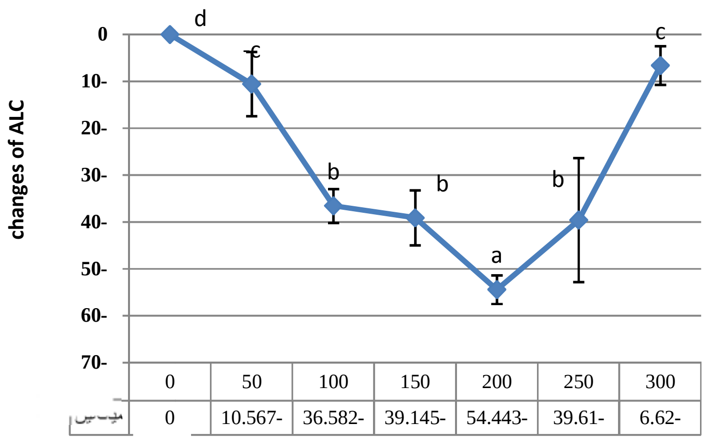
H. White sugar yield (WSY)

Meta-analysis of data from14studiesconducted showed that the effect of N rates on white sugar yield was significant, so that application of N fertilizer by 100 kg ha^{-1} increased white sugar yield but higher rates of N led to the decrease in white sugar yield. The greatest (15.96%) increase in white sugar yield was observed in 100 kg N ha^{-1} treatment, while the maximum white sugar yield reduction (27.38 % compared to control) was observed in 300 kg N ha^{-1} application (Fig. 4).



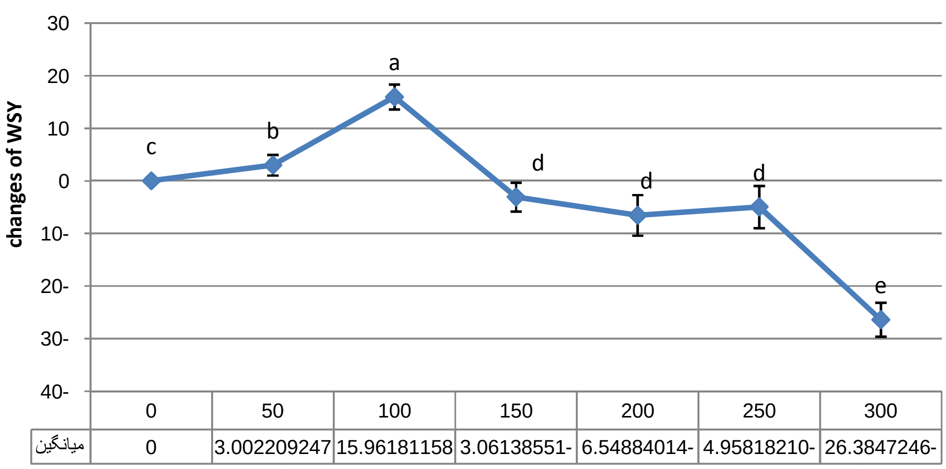
	0	50	100	150	200	250	300
میانگین	0	3.43	8.998	13.9262	40.6833	45.7325	18.2266

Fig. 6. Meta-analysis of the percent changes of Molasses sugar (MS).



	0	50	100	150	200	250	300
میانگین	0	10.567-	36.582-	39.145-	54.443-	39.61-	6.62-

Fig.7. Meta-analysis of the percent changes of Alkalinity coefficient (ALC).



	0	50	100	150	200	250	300
میانگین	0	3.002209247	15.96181158	3.06138551-	6.54884014-	4.95818210-	26.3847246-

Fig. 8. Meta-analysis of the percent changes of white sugar yield (WSY).

DISCUSSION

According to the publishes data, 0.73 % decrease by 13.58% increase was estimated compared to control treatment in sugar beet root yield by the application of 50 kg N ha^{-1}. There was 0.05-24.49% increase in root yield of sugar beet under 100 kg N ha^{-1}. The studies showed that a 14.95 % decrease by a 25.7% increase, a 17.03% decrease by 32.83%, a 26.96% decrease by a 26.82% increase and18.37% decrease by a 7.42% increase was observed in root yield at 150, 200, 250 and 300 kg N ha^{-1}, respectively. Therefore, results confirmed that optimum N for the production of root yield of sugar beet in the meta-analysis conducted was at the range of 200 to300kg ha^{-1}.These results agree with the findings of other studies (Hoffman et al., 2009; Carter 1982; Armstrong 1986). Taleghani (1998) found that adequate for optimal production of sugar beet was detected to be 240 kg ha^{-1} (as urea).

A 4.54 % decrease by a 8% increase, a 2.21% decrease by 9.8% increase, a 10. 61%-18.64% increase, a 16.98% increase by a 24.24% decrease, a 14.32% increase by a 17.9% decrease and a 683% increase by a 25.65% decrease was found in sugar content at 50, 100, 150, 200, 250 and 300 kg N ha^{-1} application, respectively. Mata-analysis of data from14 studies conducted showed that the changes in sugar content compare with control were found to be 0.89%, 0.98%, -1.35%, -0.83%, 1.43% and -1.90% at 50, 100, 150, 200, 250 and 300 kg N ha^{-1} treatments, respectively. It is presumable that given that consumers are nitrogen root yield increases by N application and there is negative correlation between root yield and sugar content, anything which reduces the root yield it improves the sugar content. Results highlighted that optimum N for obtaining the suitable sugar content was at the range of 50 to100kg ha^{-1}.

The percentage of Na, K and amino nitrogen in sugar beetroot, which are considered as the negative factors for sugar beet, were increased in accordance with N increasing. Meta-analysis of the conducted researches showed that nitrogen used to reduce the impurities in proportion to nitrogen needed to produce higher content of sugar is high because there is a negative correlation between them. According to the results, application of 50kgN ha^{-1} is recommended. In a Mata-analysis conducted on 9 varieties in 52 experiments documented, Hoffman *et al.* (2009) reported that the amino nitrogen content in environments with low nitrogen concentration was lower than that of in environments with high nitrogen concentration and the content of amino nitrogen was increased with increasing the N levels. Carter (1982) found that the Na, K and amino nitrogen increased under higher levels of N.

In reviewing the literatures, there was a 3.37 % decrease by a 14.81% increase, a 35.09% increase by a 5.05% decrease, a 36. 66% increase by 73.35% a decrease, a 80.1% decrease by a 52.56% increase, a 71% decrease by a 81% increase and a 71.06% decrease by a 22.05% increase in white sugar yield at 50, 100, 150, 200, 250 and 300 kg N ha^{-1} application, respectively. Mata-analysis of data from14 studies conducted showed that the changes in sugar content compare with control were found to be 0.89%, 0.98%, -1.35%, -0.83%, 1.43% and -1.90% at 50, 100, 150, 200, 250 and 300 kg N ha^{-1} treatments, respectively. The range of results obtained is high and are highly complex and contradictory expert advices. Mata-analysis of data obtained from the conducted studies showed that the variations in white sugar yield compare with control were found to be 4.04%, 11.81%, -2.14%, -1.26%, 0.12%, , and -17.42% at 50, 100, 150, 200, 250 and 300 kg N ha^{-1} treatments, respectively. Application of 50 to100kg N ha^{-1} was detected to be the optimum rates for obtaining the suitable yield of white sugar.

CONCLUSION

The present review indicated that sugar content and white sugar yield were increased by application of N fertilizer by 100 kg ha^{-1} but they were decreased at higher rates of N. results also showed that root yield, the percentage of Na, K, amino nitrogen and molasses sugar were increased under N application. Therefore, regarding the production of sugar is the main objective of sugar beet cultivation, on the other hand the beet sugar price is based on the sugar content in factories; farmers have to pay attention to recoverable sugar content. Thus, nitrogen should be adjusted according to the sugar production maximum which the meta-analysis performed revealed that the optimum N required was found to be at the range of100 to150kg ha^{-1}.

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