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The impact of nitrogen fertilization on raspberry yield quality under high temperature conditions

Diana-Elena BOLOHAN[1], Mariana VOLF[1], Ioana BUȚERCHI[2], Lucian RĂUS[1]

[1] University of Life Sciences Ion Ionescu de la Brad Iasi, Faculty of Agriculture, Department of Pedotechnics, e-mail: diana.bolohan@iuls.ro, mariana.volf@iuls.ro, lucian.raus@iuls.ro
[2] University of Life Sciences Ion Ionescu de la Brad Iasi, Faculty of Horticulture, Department of Horticultural Technologies, e-mail: ioana.buterchi@iuls.ro

* Corresponding author: lucian.raus@iuls.ro

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Abstract
Raspberry (*Rubus idaeus* L.) fruits are highly appreciated by consumers due to the taste but also for the benefits it has on human health. In recent years, in Romania, the areas cultivated with raspberries have increased due to market demand but also due to the profitability of the crop. Raspberry fruit is rich in vitamins and fiber, which attracts consumers looking for healthy living [5]. In this study, were monitored the effects of the nitrogen fertilizers, in different doses, on the quality of the fruits. The results in correlation with the high temperatures of the harvest period. The mineral fertilizer, ammonium nitrate, was chosen according to the soil analysis and had been used in three doses: 30, 60 and 90 kg/ha N active substance. A number of 5 samples were extracted from the harvested fruits, Heritage and Meeker variety, and subjected to laboratory analysis to determine: soluble dry matter, titratable acidity, total dry matter, average fruit weight. The application of high doses of fertilizer led to an increase in raspberry production, bigger fruits, but lower dry matter 11.6%. The highest dry matter content was obtained in the case of the unfertilized variant 14.97%. Titratable acidity was not influenced by the application of fertilizers, but there was a decrease due to the high temperatures during the harvest period. The application of nitrogen fertilizers led to higher yields. The high temperatures during harvest period have substantially changed the fruit quality indices.

Keywords: ammonium nitrate, dry matter content, fruit quality, titratable acidity

Introduction

Raspberry (*Rubus idaeus* L.) fruits are highly appreciated by consumers due to their taste and the health benefits they offer [5]. In recent years, the areas cultivated with raspberries in Romania have increased, driven by market demand as well as the profitability of the crop. A cane berry species, raspberries have short-lived woody shoots supported by a long-lived perennial root structure and are grown in temperate and frigid climates worldwide [1].

Although temperature and photoperiod alterations are crucial for environmental control of growth and development in red raspberry cultivars that bear fruit every two years, research shows that annual fruiting cultivars flower and mature at average temperatures between 15-25°C [11]. Occasionally, their floral development can begin at temperatures as high as 30°C [10]. According to [4], photoperiod treatment ranging from 8 to 17 hours did not appear to have a consistent impact on growth and flowering.

The yield and fruit quality of *Rubus idaeus* are influenced by factors such as variety, crop management, environmental conditions, irrigation, precipitation [13], fertilization (especially nitrogen), and other treatments [6]. The yield and qualitative traits of a species may also be significantly impacted by the genetic traits of the cultivars [3]. The yield may be affected by the genetic traits of *Rubus idaeus* L., such as growth capacity, fruit formation ability, ripening date, and plant structure. Higher yields could result from cultivars with more fruit per plant, better growth potential, or more favourable ripening dates [8].

Although the soil may contain large amounts of nutrients, unfavourable conditions (e.g., acid or alkaline soil, improper chemical element ratios, insoluble forms of elements, or lack of humidity) prevent plants from utilizing them [13]. Nitrogen is a key element that influences plant development, yield, and fruit quality. In addition to ensuring adequate nutrient supplies during flowering, fruit setting, and fruit development-all of which contribute to fruit tree productivity-appropriate nitrogen levels provide the material foundation for fruit tree growth [15].

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Material and Method

The study was undertaken in Iasi County, Budăi commune, on areas belonging to a private commercial company. The area is located in a moderate temperate continental climate, with an average annual temperature of 8.6-8.8 °C and an average annual precipitation of 545 mm. The soil analyses were carried out according to the ICPA Bucharest methodology. The experiment was set up on brown soil with a neuter reaction and good humus content (4%), assimilable phosphorus (46 ppm) and potassium (185 ppm) in the soil was also good.

The establishment of the raspberry plantation was done in September 2021, with a drip irrigation system. The planting distances are 0.5 m between plants and 2 m between rows. For this study, two raspberry varieties were fertilized with different doses of nitrogen: Heritage and Meeker. The experiment was replicated 3 times with one row (15 m) per replication. Following the soil analysis, 3 doses of ammonium nitrate were applied at budding and flowering phenophase.

A number of 4 fertilization variants resulted: V1 – control – unfertilized, V2 - 30 kg/ha, V3 - 60 kg/ha, V4 - 90 kg/ha

Total soluble solids (TSS.) were assessed by refractometry using a Refractometer Zeiss and the results were expressed in °Brix [7].

Titratable acidity (T.A.) was determined by titrimetric method and the results were expressed in mg/100 g product citric acid [7].

Dry matter (%) was carried out by oven drying method at 105 ± 2 °C for 4 hours and total dry matter was calculated based on the formula, T.D.M. % =100 – moisture [7].

Results and Discussion

During the study, an increase in fruit weight proportional to the increase in nitrogen dose was observed. This increase was 24% between N0 and N90 for the Heritage variety and 33% for the Meeker variety. A slight decrease in fruit mass was also noted within the same fertilization treatment, from the first to the third harvest, likely due to the high temperatures during the fruit formation and ripening period.

The results from this study indicate a positive influence of nitrogen dose on fruit weight. The highest 100-fruit weight was obtained when fertilizing with 90 kg N/ha for both varieties: 335g for the Heritage variety and 394g for the Meeker variety. Small differences were observed between the 90 kg and 60 kg N/ha treatments. The lowest fruit weight values were recorded in the unfertilized variant (Figure 1).

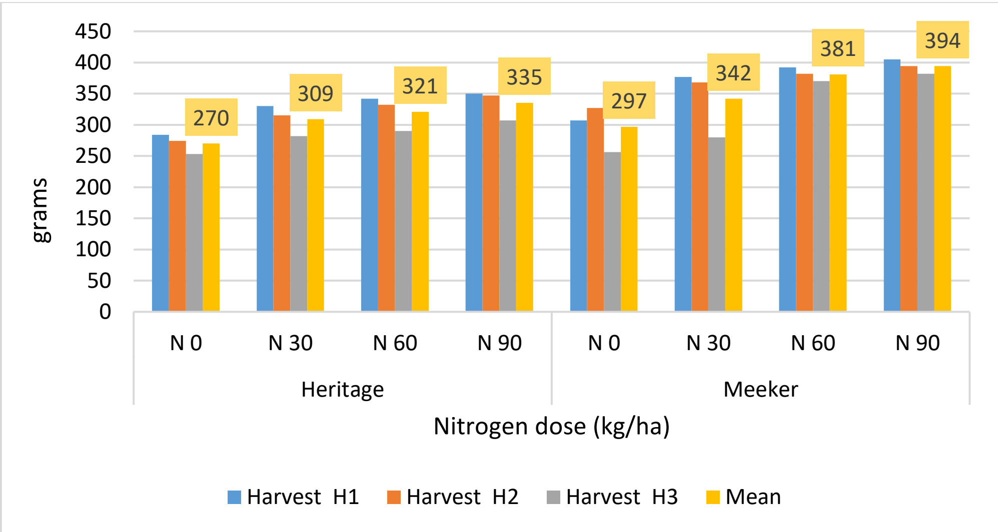

Figure 1. Influence of cultivar, fertilization and harvest temperatures on 100 fruits weight (grams)

Regarding the dry matter content of the fruits, an inversely proportional relationship was noted with the increase in nitrogen dose. The highest values of total dry matter content were observed in the unfertilized variant. The increase in dry matter content has a negative impact, as it leads to drier fruits. This effect is particularly pronounced in the Meeker variety, which is used for juice and wine production (Figure 2).

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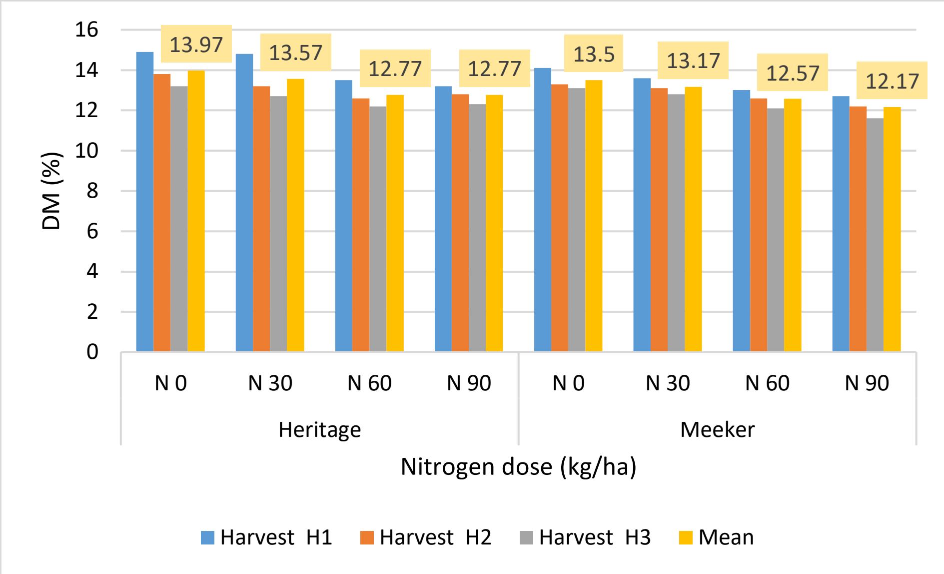

Figure 2. Influence of cultivar, fertilization, and harvest dates on fruit dry matter content (D.M. %)

The soluble solids content (SSC) of the raspberries was not significantly influenced by the nitrogen dose used in fertilization. For the Heritage variety, SSC values ranged from 9.9 to 10.1 °Brix, while for the Meeker variety, SSC ranged from 9.9 to 10.7 °Brix. The highest SSC values were observed in the fertilization variants with 30 and 60 kg N/ha, showing a difference of 0.6 to 0.7 °Brix compared to the control (Figure 3).

The fruit titratable acidity (expressed as % citric acid) showed similar values across the different fertilization treatments, indicating that nitrogen application at various doses did not have a significant impact on acidity levels (Figure 4).

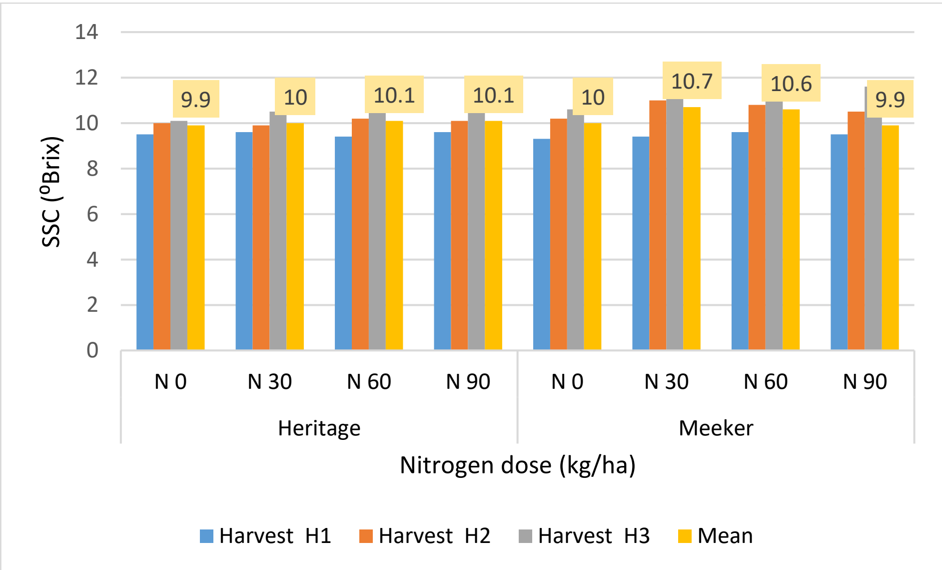

Figure 3. Influence of cultivar, fertilization, and harvest dates on fruit soluble solids content (ºBrix)

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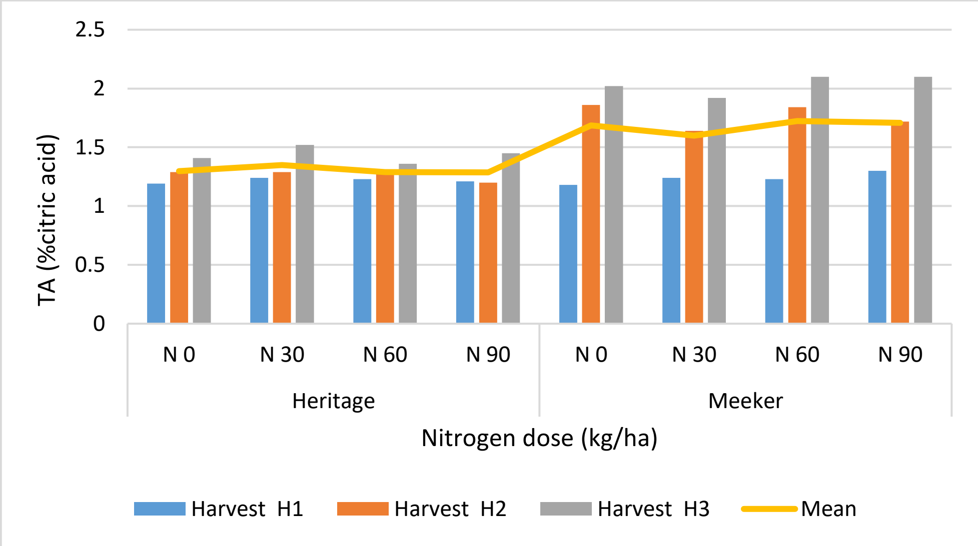
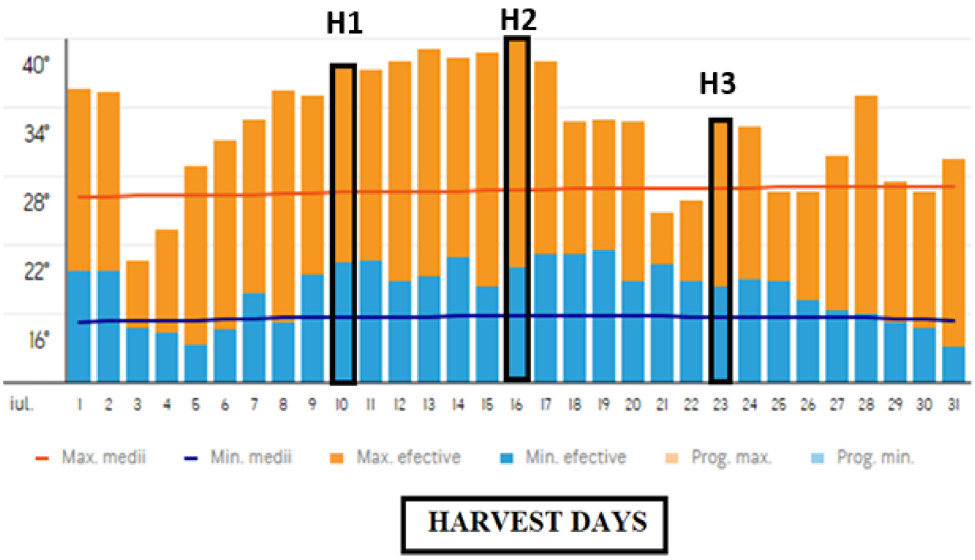


Figure 4. Influence of cultivar, fertilization, and harvest dates on fruit titratable acidity (% citric acid).

The results obtained indicate that nitrogen application at varying doses has a greater impact on production than on quality indicators. Literature suggests that high nitrogen doses positively affect plant growth primarily in soils with low or moderate nitrogen or organic matter content.

These findings align with other studies on raspberries, which show that large nitrogen doses have a reduced effect on fruit quality. However, inadequate nitrogen supply leads to significant declines in production.

Temperatures exceeding 30°C during the flowering period significantly hinder pollen viability and disrupt the normal progression of pollination and fertilization (Fig. 5). This results in poor fruit set, which leads to a reduced number of fruits and variability in their size and development. Elevated temperatures during the flowering phase can inhibit fertilization, thereby reducing crop productivity [4,10,11].



***H 1st (34ºC) — 10.07, H 2nd — 16.07 (30ºC), H 3rd — 23.07 (26ºC).**
Figure 5. Temperatures in July, 2024 (ºC)

Excessive heat also accelerates ripening, limiting the time for the accumulation of sugars and phenolic compounds. As a result, fruits may have lower soluble solids content (°Brix), reduced flavour, and diminished nutritional value. Research shows that high temperatures during ripening negatively affect sugar metabolism and the synthesis of secondary metabolites, including antioxidants and aroma compounds [1,2,9].

The response to nitrogen fertilization is closely linked to the soil's nitrogen content. When soil nitrogen levels are high, the benefits of additional fertilizer become less pronounced. Plants in such soils already have sufficient nitrogen, so additional fertilization may not significantly improve yield or productivity. This is especially true for soils rich in organic matter, which release nitrogen over time.

Several studies confirm that increasing nitrogen doses in soils with high organic carbon content does not necessarily lead to increased yields. In some cases, yields from fertilized plots were similar to those from unfertilized plots, indicating that nitrogen availability from organic matter can reduce the need for external fertilization.

For example, Sønsteby et al. (2009) found that in soils with sufficient organic carbon, nitrogen fertilization did not significantly increase raspberry yields. This trend is observed in many cropping systems, where organic-rich soils buffer the effects of additional nitrogen.

Similarly, Buskienė and Uselis (2008), found that nitrogen fertilization had a reduced effect on raspberry growth and yield when applied to soils rich in organic matter. These results are consistent with those of Lu et al. (2022), who suggested that nitrogen fertilized systems show weaker responses when soils already contain substantial available nitrogen [3,6].

Furthermore, Rempel et al. (2004), highlighted that nitrogen uptake and partitioning in raspberries are influenced by both the soil's nitrogen supply and the timing of fertilization. In nitrogen-rich soils, plants' ability to absorb and utilize additional nitrogen is limited, reinforcing the idea that the response to fertilization is diminished when soil nitrogen levels are high [8].

Conclusions

The application of different doses of nitrogen to raspberries is effective in soils with poor and average nitrogen and organic carbon supply. In the present study, the highest yields were recorded when fertilizing with 90 kg N/ha.

The influence of the dose on soluble solids content and titratable acidity is reduced. Quality indices are primarily influenced by climatic conditions during the fruiting period.

Nitrogen is a crucial nutrient for plant growth, but the existing nitrogen supply in the soil—particularly in soils with high organic carbon content—can significantly reduce the effectiveness of additional nitrogen fertilization. This understanding is important for optimizing fertilization strategies, especially in sustainable agricultural systems where over-fertilization can lead to nutrient imbalances and environmental concerns.

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