Impact of varying plant densities on two industrial hemp cultivars grown in the Manawatu

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Abstract

Industrial hemp (*Cannabis sativa* L) is a fast-growing annual multi-purpose crop grown for its fibres, hurd, seeds and pharmaceuticals. The commercial production of industrial hemp is strictly legislated and only approved cultivars with delta-9-tetrahydrocannibinol (THC) levels under 0.35% are permitted in New Zealand. The effect of varying plant densities was studied for two industrial hemp cultivars (Fasamo and Ferimon 12) in the Manawatu region. Four planting densities (40, 80, 120 and 160 plants/m^2) at two row spacings (15 cm and 30 cm) were evaluated. Ferimon 12 produced the greatest average biomass of 34.6 t/ha with 160 plants/m^2 at a 30 cm row spacing. Cultivar not plant density or row spacing had the most effect on agronomic measurements. Ferimon 12 produced longer, heavier stems with higher overall biomass compared to Fasamo regardless of plant density or row spacing. Individual stem weight decreased as plant population increased for both cultivars. Higher planting density and closer row spacing improved weed suppression.

Additional keywords: *Cannabis sativa* L., plant density, sowing rates, row spacing, stem dry yield, total fresh biomass, weed control, fibre, fiber, Fasamo, Ferimon 12.

Introduction

Hemp (*Cannabis sativa* L.*)* is a fast-growing plant with a history of cultivation dating back to 6000 years before present (Sawler *et al.*, 2015). This annual herbaceous species originated in Central China (Andre *et al.*, 2016). Hemp is a versatile, high yielding plant, grown across the globe for food, fibre and medicine (Salentijn *et al.*, 2014). Hemp fibres have a range of uses including the production of paper, clothing, insulation and other industrial applications (Dhakal and Zhang, 2015). Due to hemp's ability to produce a biomass of 25-39 t/ha (Jankauskiene and Gruzdeviene, 2012), hemp absorbs more carbon dioxide than any other known commercial crop (Vosper, 2011). This carbon negative plant has potential to become a successful industry for New Zealand as the demand for sustainable agricultural practices continues to increase along new legalized uses for human food and medicinal applications.

Hemp fibre is extremely robust and diverse, but as a natural fibre, it often varies in size and quality due to different growing conditions (Fernandez-Tendero *et al.*, 2017). The fluctuating qualities of hemp fibre is one of the main disadvantages of the product when compared to synthetic fibres (Fernandez-Tendero *et al.*, 2017). Hemp fibre is made up of two main fibre types: 1) bast fibres (vascular tissue), these are long and suited for a large range of textile uses; 2) hurd fibres (woody inner core), these fibres are located within the inner woody pith of the stem and are shorter than bast fibres (Fortenbery and Bennet, 2004). The automotive industry has been incorporating hemp bast fibres into car bodies and upholstery (Karus and Kaup, 2002). For many years hurd fibres have mainly been used for low-value animal bedding. However, research is revealing many promising high-value uses for the substance, e.g. uses of hemp hurd fibres as insulation in the building industry (Nguyen *et al.*, 2009) and so-called hemp concrete or 'hempcrete' as a known, sustainable building material with excellent mechanical and thermal properties (Elfordy *et al.*, 2007).

A change in NZ government legislation in 2001 made it possible to grow industrial hemp under strict licensing laws (McPartland *et al.*, 2004). Delta-9-tetrahydrocannibinol (THC) is the euphoric psychoactive substance in cannabis. The Ministry of Health in New Zealand has approved 12 industrial hemp cultivars with THC levels under 0.35% to be grown under license (MoH, 2017). Fike (2016) outlines that while hemp fibres have certain advantages over petroleum and glass-based fibres, cost is a major constraint on their use.

Hemp displays a prolific growth rate and a natural resistance to pests and diseases. Hemp plants can grow up to 5 m tall in ideal conditions with the support of a strong, woody stem. Both dioecious and monoecious hemp cultivars exist (Bouloc *et al.*, 2012). Dioecious plants exhibit only male or female reproductive organs on an individual plant, while monoecious plants have both male and female structures on the same plant. Both types can be used for grain and fibre production. Hemp can tolerate heat well and thrives in full sun, but performs poorly in cold, shaded environments and is intolerant to waterlogged soils (Small *et al.*, 2003). Hemp cultivars available in New Zealand come in a range of relative maturities. They are all short-day types requiring shortening days to turn from vegetative to reproductive growth (Merfield, 1999). Plants have a primary taproot which can reach 2.5m deep, allowing the plant to exploit nutrients and water effectively (Burczyk *et al.*, 2008).

For fibre production, hemp is grown at densities ranging between 40 and 400 plants/m^2 (Van der Werf, 1995). Hemp grown in Europe for fibre has been reported to yield up to 25 TDM/ha (Struik *et al*, 2000). Understanding the relationship between plant density, biomass yields and quality will allow the grower to manage these factors to realise a crop suited to the intended end use. Previous studies conducted by Kerckhoffs *et al.*, (2017) provide an understanding of the relationship between hemp seed rates and plant density. The purpose of this paper was to investigate the effect that planting density has on the biomass harvested from Ferimon 12 and Fasamo at two different row spacings.

Materials and Methods

Experimental details

The trial was conducted during the 2017/2018 season at Massey University's Horticultural Crop Unit, Palmerston North (40° 38' S, 175° 61' E). The soil type is Turitea silt loam with adequate drainage and water holding capacity. Soil quality testing conducted by Hill Laboratories on several soil samples taken from the field revealed that the soil had a pH of 6, an Olsen P-value of 47mg/L and a CEC of 15. All nutrients were found in adequate levels with an exception of sulphur which was very low at 4mg/kg.

The experiment consisted of 64 randomised individual plots, each plot was 4.5m x 6m. Two monoecious cultivars called Ferimon 12 and Fasamo were used for this trial. For the remainder of this paper, Ferimon 12 will be referred to as Ferimon. The hemp cultivars were sown at 15 cm and 30 cm row spacing at four different densities, aiming for 40, 80, 120 and 160 plants/m^2. The sowing rates required to achieve densities within this range for these cultivars was investigated by Kerckhoffs *et al.*, 2017. Achieving similar densities has enabled us to further investigate the impact of density on the above-ground biomass yields of these cultivars. Four replicates were established for each treatment. Seeds were acquired from Midlands Seeds and direct drilled using a cone seed driller at varying rates on the 5th of December 2017.

The first seedling emergence was noted on the 12th of December. By the 27th of December, initial counts were made to determine the plant density within the plots. A one square metre sub-plot was selected and marked within each of the 27m^2 plots. Densities within the targeted sub-plots were measured and each one was hand thinned to achieve the desired density. This processing of hand thinning is not typical in commercial hemp production, but was necessary to achieve replicates of the planting densities.

Weekly measurements of plant height were made and the crop was observed regularly to identify any potential pest or disease damage. No fertiliser was applied to the crop and no pest or disease control was implemented during the experiment. The hemp crop was harvested on the 14th of February 2018, 70 days after sowing. This is a relatively short season, the plants were harvested at this stage as their seeds were ripening. It is common practice to harvest a hemp fibre crop before initial seed maturity (Hoppner and Menge-Hartmann, 2007). Each of the targeted square metre sub-plots were harvested by hand. The hemp plants were pulled from the ground and kept in the shade to slow the rate of transpiration. Once the hemp plants were harvested and bundled, they were stored in a temperature controlled environment for further data collection. All weeds within the square metre plots were also pulled out and collected for analysis.

The harvested plants were counted once more in the lab and their roots were cut away before the fresh weight was measured. This fresh weight included the entire length of the plant stems, unlike commercial operations which typically harvest the hemp stems above ground-level. An average height was determined from each of the sub-plots. Plants which were less than half the average height were weighed and removed from the bundle for each sub-plot. The abnormally small plants were removed from the bundles so that future fibre quality testing done on these specimens would be indicative of the typical plants produced at these densities. A representative sample of four plants was randomly compiled from each block for analysis. The stems from each bundle were oven dried at 72°C for three days to obtain stem dry weight. Samples were sent to Massey University, Auckland for additional analysis of the fibres.

Climate

The Manawatu region has a relatively mild climate. However, Palmerston North experienced its hottest summer in 90 years during 2018. This hot weather was accompanied by a major drought for the region. Climate data was obtained from the Palmerston North weather station which was located within 500 metres of the crop. Weather data was provided by CliFlo (NIWA, 2018). The weather data showed that during the 70 days of growth, the hemp crop was exposed to 446.4 hours of bright sunshine, this is an average of approximately 6.4 hours of bright sunshine each day.

The total rainfall recorded during the 70 day life cycle of the hemp, from sowing to harvest was 177.4 mm. A soil moisture deficit during the early stages of development was corrected with 16mm of irrigation during the first two weeks after sowing. Irrigation was used to ensure that conditions were suitable for germination. Due to limited resources, the crop was still exposed to some soil moisture deficits during the early stages of development.

Statistical analyses

Statistical analyses were completed using MINITAB version 17 (Minitab Inc., State University, Pennsylvania, USA). All measures were tested for normality of distribution using Kolmogorov-Smirnov method and were found to be normally distributed. Differences between means, in relation to treatment factors, were tested by one-way analysis of variance (ANOVA), blocked on treatment. Comparisons between treatment results were carried out using Tukey tests. Based on this, means represented within the results section which do not share a letter are significantly different from one another. Statistical significance is declared when $P<0.05$.

Results and Discussion

Plant height

The mean height of Ferimon plants was significantly higher at 207cm compared to the mean height of Fasamo plants at 150cm ($P<0.05$). Fasamo began flowering only 4 weeks after sowing (early January), this early flowering was expected as Fasamo is an early-flowering cultivar which does not require the accumulation of short-days like Ferimon. Early flowering in Fasamo resulted in the plants being far shorter when compared to the Ferimon plants (Figure 1). It is important to note that this early flowering may be avoided by sowing earlier in the season.

Within a cultivar, planting density did not have a significant impact on the heights of the plants ($P>0.05$) (Figure 1). This data combines the results found from plots sown at 15cm and 30cm. Analysis of the results revealed that the mean plant stem height did not change significantly across four densities (plants/m^2) within each cultivar.

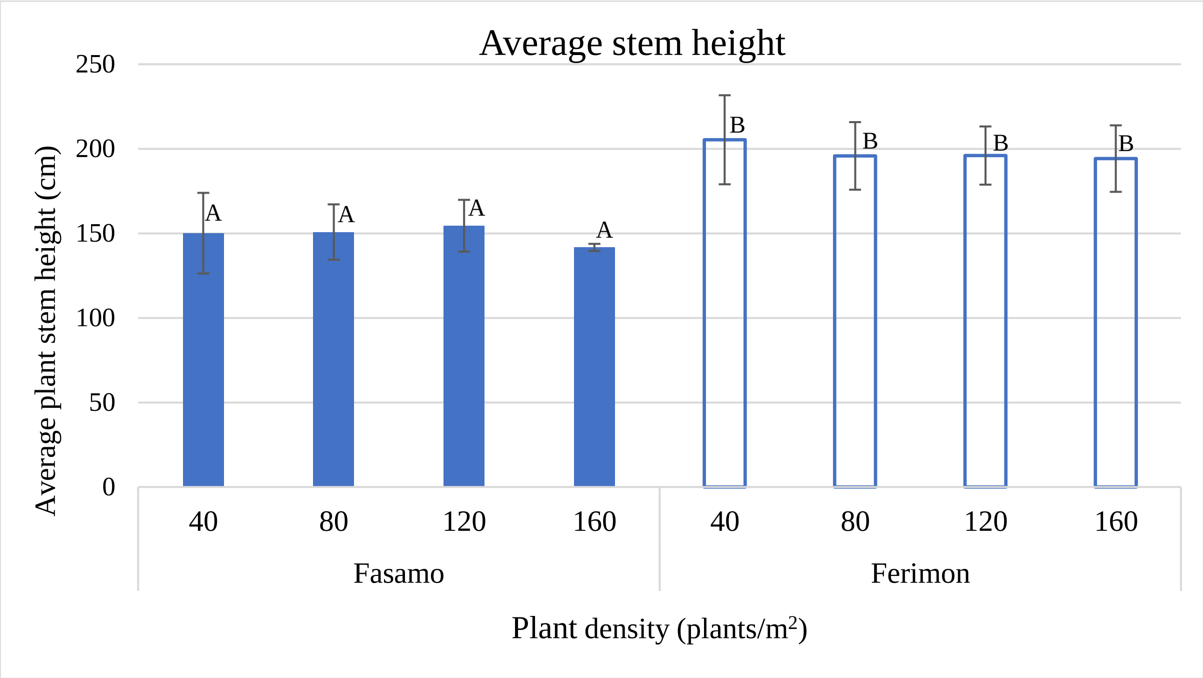

Figure 1: Average plant stem height ± SE (cm) for hemp cultivars Fasamo and Ferimon at four planting densities (plants/m2), averaged for both row spacings.

Weed suppression

The results illustrated in Figure 2 and 3 indicate that as plant density increased, the mass of the weeds present within the plot decreased ($P<0.005$). Growing hemp at high densities results in a canopy which effectively shades the ground, preventing the germination of weeds and reducing competition for the crop (Vera and Hanks, 2008). Weeds compete with the crop for water, nutrients and light if they are able to grow fast enough to shade the hemp plants. At a 15cm row spacing, the average fresh weed weight (kg/m^2) decreased significantly when planting density increased from 40 to 80 plants/m^2. At a row spacing of 30cm, the average fresh weed weight did not decrease significantly when planting density increased across both cultivars. Growing these hemp cultivars at a 15cm row spacing at a density of 80 or more plants/m^2 will reduce weed presence, thus reducing the impact of weed competition or the need weed control. Figure 4 demonstrates how effective Ferimon is at forming a canopy at a 15 cm row spacing only 29 days after sowing.

Stem weight

The average stem weight results across different densities for Ferimon and Fasamo are combined in Figure 5 and were statistically significant ($P<0.05$). A Tukey analysis of the means reveals that the difference between 40 and 160 plants/m^2 was not significantly different.

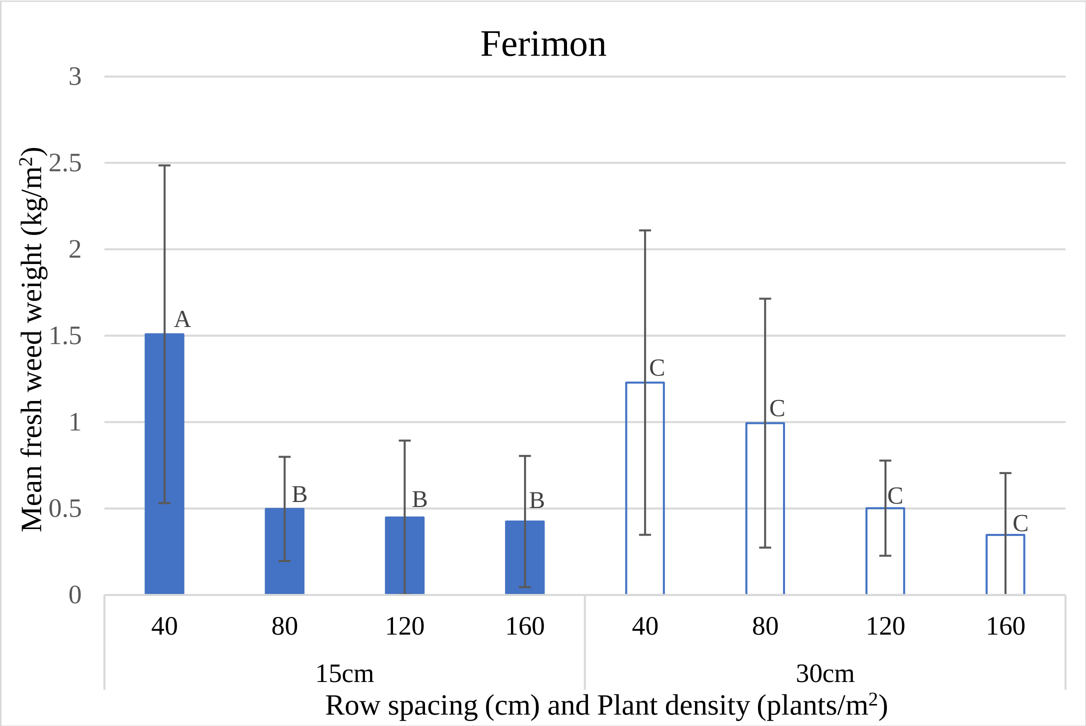

Figure 2: Mean weed weight ± SE (kg/m2) at four plant densities (plants/m2) and two row spacings (15 and 30 cm) for hemp cultivar Ferimon.

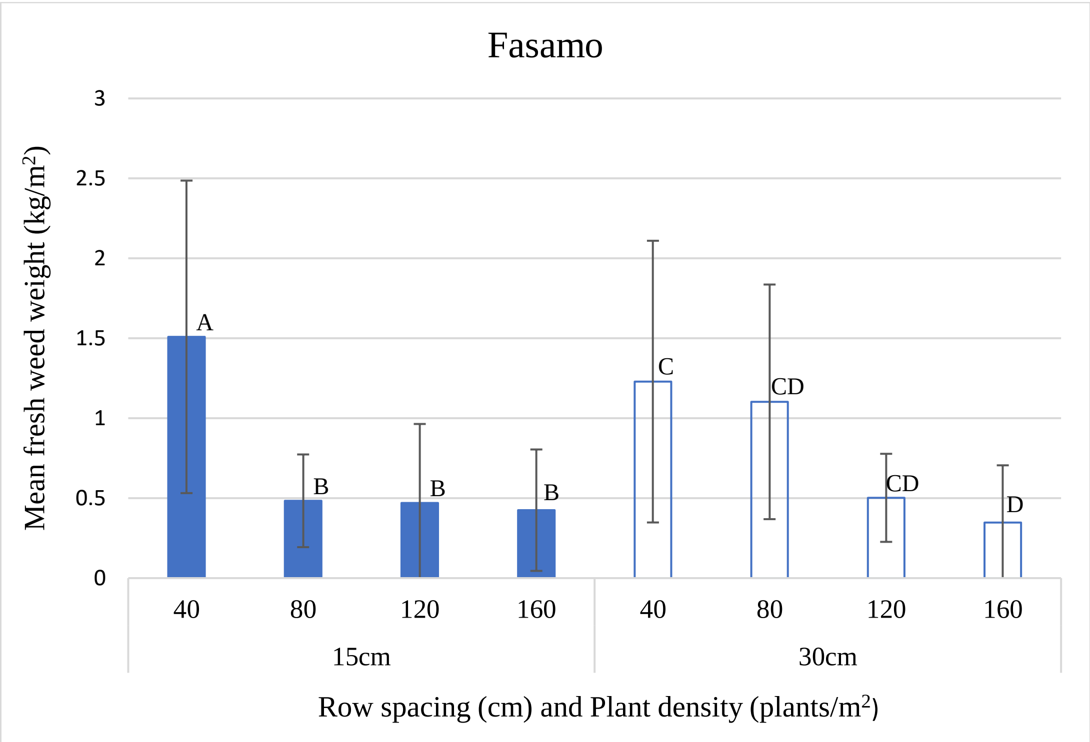

Figure 3: Mean weed weight ± SE (kg/m^2) at four plant densities (plants/m2) and two row spacings (15 and 30 cm) for hemp cultivar Fasamo.

Figure 4: Ferimon plants grown at 120 plant/m2 with a row spacing of 15cm form a dense canopy only 29 days after sowing

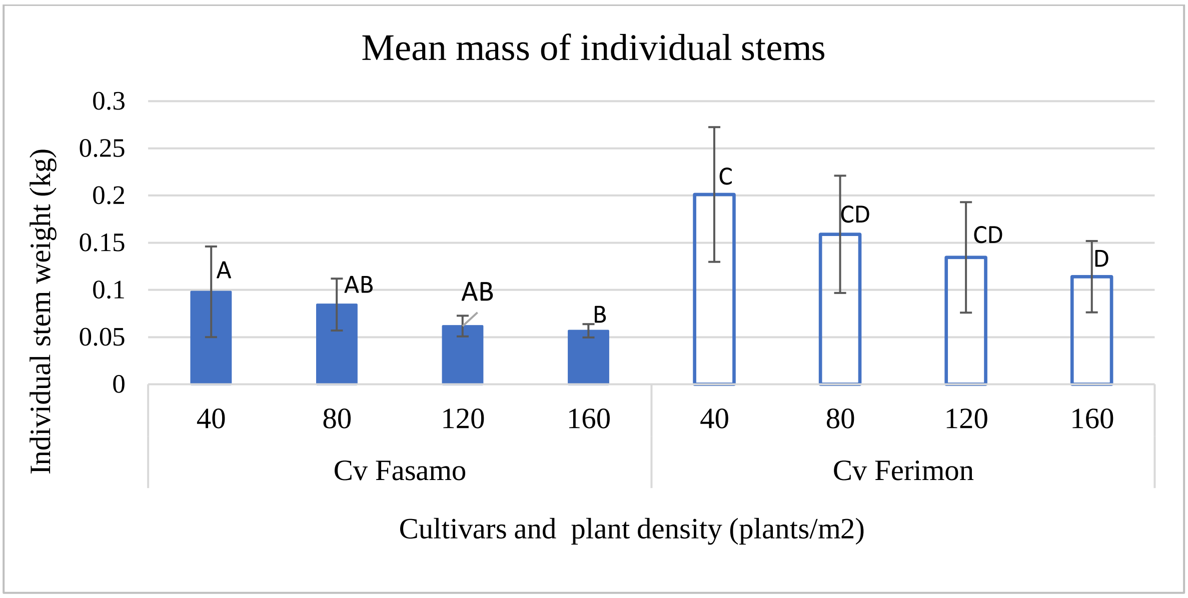

Figure 5: Mean fresh weight of individual stems ± SE (kg) for hemp cultivars Fasamo and Ferimon at four plant densities (plants/m^2) averaged from two row spacings.

Biomass harvested

Figure 6 and 7 illustrate the impact that density and row spacing has on the above-ground fresh biomass harvested (P>0.05). These results show that planting density and row spacing will not directly influence the average above-ground biomass harvested from the fibre hemp crop. This data shows that Fasamo produced a lower level of biomass than Ferimon; this supports the findings presented by Kerckhoffs *et al.*, (2017). These biomass results are supported by Hoppner and Menge-Hartmann (2007) who found that Fasamo produced significantly lower biomass yields than other, late maturing cultivars.

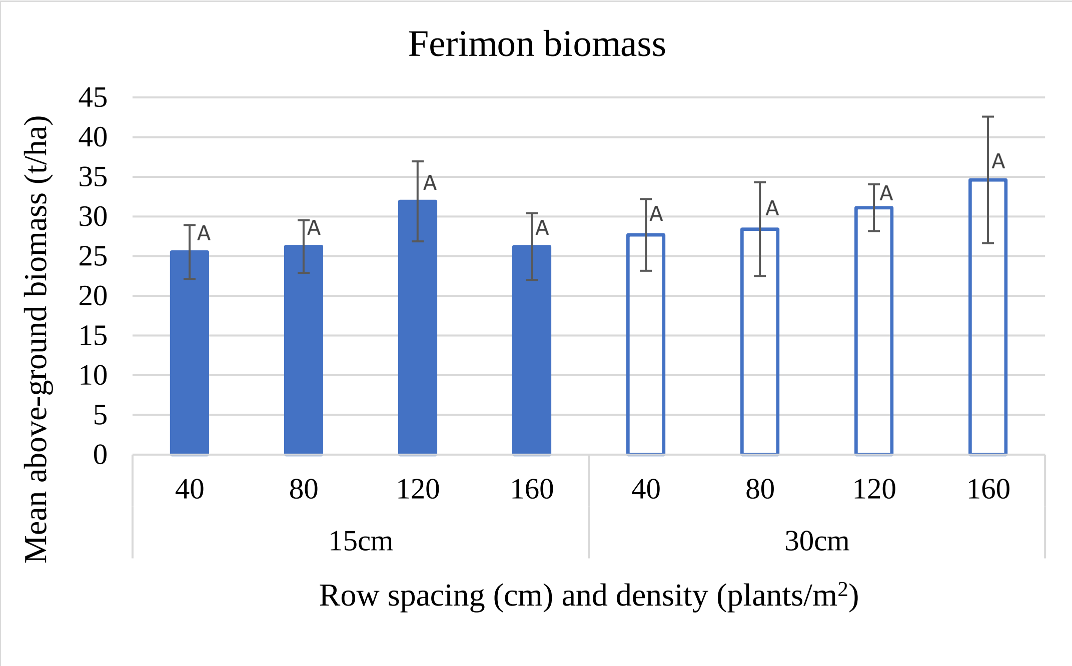

Figure 6: Average above-ground fresh biomass ± SE (t/ha) for hemp cultivar Ferimon at four plant densities (plant/m2) for two row spacings (cm).

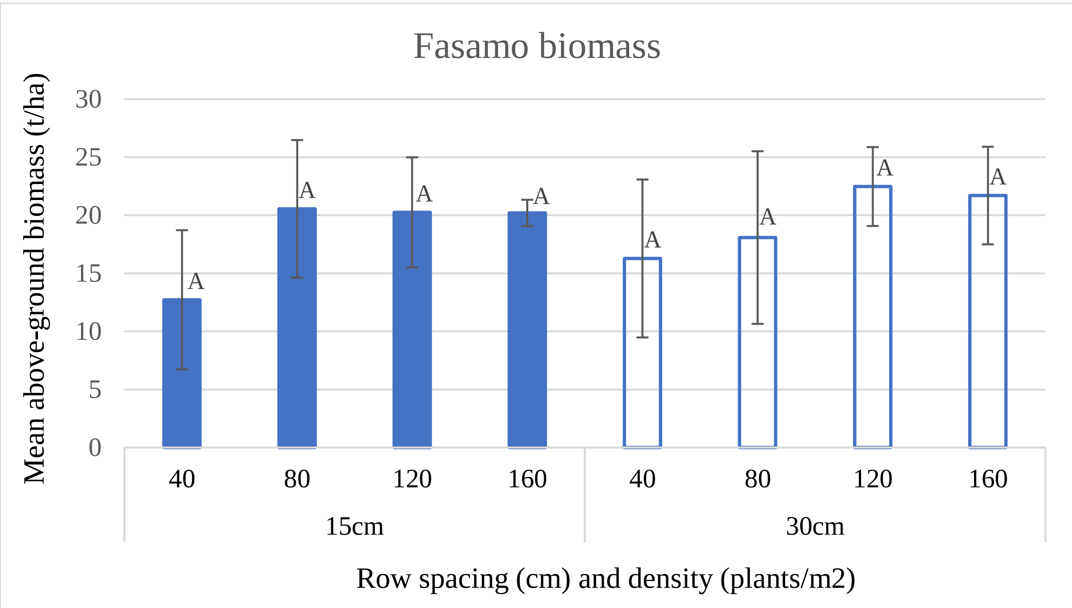

Figure 7: Average above-ground fresh biomass ± SE (t/ha) for hemp cultivar Fasamo at four plant densities (plant/m^2) for two row spacings (cm).

Bird damage

Hemp seeds are nutritious and palatable to birds. An influx of birds was seen as the crop came into maturity shortly before harvest time. Small birds did damage the stems of the plants and are unlikely to have an impact on fibre quality. However, pukeko (*Porphyrio melanotus)* were sighted within some areas of the hemp crop eating mature seed. The weight of these large native birds caused the stems of several plants to bend and snap. The pukeko also attempted to make nests within the crop and flattened entire areas of hemp plants. This destructive behaviour has been reported by Craig (1980). The damage caused by the pukeko may have a direct impact on the quality of the hemp fibres. Micro fractures reduce fibre quality as they decrease the tensile strength of the fibre by creating weak-points which will snap under lesser force than those fibres which have not been damaged in this way.

Conclusions

There are benefits to growing hemp at a high density with regards to its ability to suppress weeds. Growing hemp at a density of 80 plants/m^2 and higher at a 15 cm row spacing could reduce the need for weed management in this crop. A planting density of 160 plants/m^2 is required for effective weed suppression when hemp is grown at a 30cm row spacing. When growing these cultivars, density will not influence the average height of the plants. Ferimon outperformed Fasamo in terms of average yields across all treatments. The early-flowering behaviour observed in Fasamo suggests that this cultivar may be more suited as a dual-purpose crop for seed oil and fibre production or should be planted earlier to have more of a chance to accumulate biomass prior to turning reproductive. The biomass harvested from these hemp cultivars was not be affected by changing the planting densities. However, higher planting densities will result in smaller individual stem weights, the impact that these smaller stems has on the composition, quality and yields of these hemp fibres is currently being investigated by Massey University, Auckland.

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