Evaluating the Use of Alfalfa as a Surface Mulch in Corn Cropping Systems

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Summary

Organic systems without livestock are common throughout much of the Corn Belt, requiring organic corn and grain growers to find ways to supply nitrogen (N) to their crops without manure. While alfalfa and other forage legumes grown in rotation with organic corn can generally meet crop needs, it is difficult for farmers without livestock to justify maintaining the necessary acreage of perennial forage for this practice. When organic alfalfa is grown, the hay may be sold, often resulting in the export of more than 100 kg N/ha off the farm. Although alfalfa mulch has been investigated as an N source for vegetables and small grains, little work has been done to confirm how well it can supply N to organic corn, a high N-demanding crop. Our project evaluated the use of on-farm produced alfalfa mulch as a nutrient source for production of organic corn. We found the alfalfa mulch had a positive effect on corn grain yields at one of our sites, but not the other. Alfalfa mulching to supply N affected early season corn growth and available soil N, but these effects were not consistently related to final corn grain yield, indicating that N in mulch may be lost. Despite the mixed results in the corn grain yields of our experiment, we believe alfalfa mulch has potential as a fertilizer source in organic systems.

Introduction

We evaluated the use of a novel alfalfa mulch system to supply nutrients for organic corn. Potential benefits of the alfalfa mulch system include: (1) keeping a perennial alfalfa crop in the rotation for its proven soil health and weed control benefits, (2) reducing the export of nutrients off-farm, and (3) reducing tillage and weeds, especially where the mulch is surface applied and unincorporated. The intent of this sustainable system is to encourage the inclusion of alfalfa in rotation on organic farms without livestock, and to allow for a closed on-farm system of nutrient recycling. Historically, alfalfa has been grown as a livestock feed with the additional benefit of supplying N to subsequent crops in rotations. Today, many organic producers have operations without livestock (MDA, 2007) and therefore have little or no access to manure and less motivation to grow forage legumes like alfalfa in their rotations. An organic producer survey found that 80% of Minnesota organic enterprises had crops like corn as their major enterprise, but less than 50% had livestock (MDA, 2007). When producers without livestock do grow alfalfa for its soil-building attributes, they frequently harvest the alfalfa as hay and sell it, thus exporting the above-ground nutrients off-farm. Where manure and compost are available and applied as a source of nitrogen, long-term applications can lead to excessive levels of soil phosphorus, unlike green manures which do not pose this risk (Cherr et al., 2006). Prior to our project, there had been limited research on the use of alfalfa mulch as a fertilizer for crops. One experiment conducted on organic spring wheat found that unincorporated alfalfa mulch provided the same yields as synthetic fertilizers (Wiens et al., 2006). The highest rate of alfalfa mulch also provided additional benefits such as higher grain protein, weed suppression, and moisture conservation (Wiens et al., 2006). In another experiment, alfalfa maintained as a soil surface mulch in an apple orchard floor for seven consecutive years showed an increase in total soil C and N compared to control soils (Neilsen et al., 2003). In a tomato production system, an alfalfa mulch mixed with straw was surface applied (Greenland, 2001). The mix delayed maturity of the tomato plants, possibly due to an excess of N or reduced soil temperature.

An organic farmer in Minnesota, Carmen Fernholz, experimented with incorporating alfalfa mulch to fertilize grain crops through a farmer grant from the Minnesota Department of Agriculture (Fernholz, 2012). While his results were not analyzed statistically, he found a trend of increasing corn yields with alfalfa mulch – 8855 kg/ha (141 bu/ac) for the control versus 9608 kg/ha (153 bu/ac) for the highest alfalfa mulch rate. He believed the alfalfa mulch system had promise if the field operations to apply mulch could be developed to be efficient on a large scale.

Materials and Methods

Experiments to evaluate the use of alfalfa as a mulch to supply N for corn production were conducted in 2012 and 2013 at the University of Minnesota's Sand Plain Research Center, Becker, MN and at the Southwest Research Center, Lamberton, MN. The soil at Becker is irrigated, well drained Hubbard loamy sand, and the soil at Lamberton is a Normania – Ves complex loam (fine – loamy, mixed, superactive, mesic Aquic Hapludoll). Both sites followed a small grain (winter rye or wheat) in rotation to draw down residual soil N that often remains after a soybean crop in rotation. The soil was cultivated for weed control in late summer after harvest of the small grain. Treatments were arranged in a randomized complete block design with four field replicates per site (52 total plots per site). Plot were 3 x 9 m, with corn rows 76 cm apart, for a targeted population of 74,000 corn plants per hectare.

Treatments consisted of three application rates in the fall and the spring of green alfalfa herbage that was cut from adjacent alfalfa fields and uniformly broadcast, fall- and spring-applied livestock manure, and a no-fertilizer check. Fall treatments were applied following harvest of the small grain crop, and spring treatments were applied before corn seeding. Fresh alfalfa herbage was applied in amounts to achieve N rates of 100, 200, and 300 kg per hectare. Manure was applied to achieve a rate of 100 kg N per hectare in the fall and in the spring. In the fall, fields were cultivated or disked to kill weed growth before treatment application. The alfalfa and manure were broadcast and were disked lightly after application to incorporate the mulch and manure.

For the spring applications, the manure was applied in early May and the soil was disked for shallow incorporation and to provide a seedbed for corn planting. An adapted organic corn hybrid was planted mid-May. Two cultivations were then made to kill weeds in the emerging corn. At corn growth stages of V2-3, green chopped alfalfa herbage was uniformly applied (Figure 1). Both fall and spring treatments were cultivated at least two additional times and weeds were controlled.

Figure 1. Spring-applied alfalfa mulch at the Becker site.

Actual application rates of alfalfa herbage and manure to achieve the target N rates were based on measurement of alfalfa herbage and manure nitrogen concentration prior to application. Depending on the location and time of year, the alfalfa varied from late vegetative to early flowering stage. Green chopped alfalfa herbage was harvested from adjacent farm fields. The range of nitrogen applied to corn as alfalfa mulch or manure was based on University of Minnesota soil test recommendation for each site.

<u>Data collection:</u> Corn biomass was measured at 15, 30, and 45 days after seeding by harvesting a representative area in each plot. Biomass was dried at 49°C and dry weight determined. Biomass was then ground and analyzed for N content using NIRS. At grain maturity, corn grain yields were measured by harvesting a representative area of each plot. Grain was separated from cobs and dried at 35°C. Yield of herbage and grain was expressed on an area basis.

Soil cores were collected both prior to spring treatment applications and at 15, 30, and 45 days after seeding to a depth of 31 cm. Samples were taken from 3 quadrats, one per collection date and sampled between corn rows. All soil samples were taken with either manual hand soil probes or a Giddings hydraulic soil coring probe. Soil samples at spring baseline were analyzed for soil fertility status pH, P, and K and plant available N (nitrate and ammonium). All other samples were combined according to depth by date, air dried at room temperature, and dry sieved to a <4-mm fraction and subsampled for processing. Soil pH, P, and K levels were adequate for corn production and are not discussed in this report.

Plant available and total N was determined by potassium chloride extraction, where soil was shaken in 2 M KCl at 150 rpm for 1 hour; centrifuged at a rate of 4000 RPM's for 12 minutes, and analyzed for nitrate, ammonium, and total N using an automated flow injection analyzer (QuickChem FIA$^+$ 8000 Series, Lachat Instruments) (Hoffer, 2003; Knepel, 2003).

Statistical analysis: Data was analyzed using the MIXED procedure of SAS (version 9.4; SAS Institute Inc., Cary, NC). Individual plots comprised the experimental unit, and statistical significance was set at $P \leq 0.05$. Differences among environments resulted in significant interactions ($P \leq 0.05$) between location and cutting treatment; therefore, locations were analyzed and reported separately. Replicate was considered a random effect; cutting treatment and cultivar were designated as fixed effects.

Results – Corn Grain Yield

In 2012 at Becker, fall-applied alfalfa had similar grain yields to the non-fertilized check (Figure 2). The two highest rates of fall-applied alfalfa yielded similarly to the fall-applied manure. Corn grain yields were greater following all three spring-applied alfalfa treatments than the non-fertilized check, and corn yields following spring-applied alfalfa at 200 kg N/ha and 300 kg N/ha were greater than spring-applied manure at 100 kg N/ha, and the non-fertilized check (Figure 2).

In 2013 at Becker, corn grain yields following the lowest rate of alfalfa application in both spring and fall were similar to the non-fertilized check (Figure 3). Conversely, corn grain yields following both the fall- and spring-applied alfalfa at the two highest rates had yields that were greater than the non-fertilized check. Corn yields following fall- and spring-applied alfalfa at the 200 and 300 kg N/ha rates were similar to or greater than the fall and spring manure treatments, respectively (Figure 3).

At Lamberton in 2012, fall-applied alfalfa treatments performed similarly and corn grain yields were lower than the non-fertilized check and the fall-applied manure (Figure 4). The spring-applied alfalfa treatments yielded lower or similarly to the check. Only the highest rate of spring-applied alfalfa resulted in corn yields that were comparable to spring-applied manure (Figure 4). At Lamberton in 2013, grain yields were similar among all treatments (Figure 5).

In three of the four site-years, corn yields in this study were much lower than is typical for organic systems in Minnesota. The average yield in 2012 was 1821 kg/ha (29 bu/ac) for Becker and 2386 kg/ha (38 bu/acre) for Lamberton due to severe drought during the second half of the growing season. Average yields increased in 2013 to 3266 kg/ha (52 bu/ac) and 9106 kg/ha (145 bu/ac) in 2013 for Becker and Lamberton, respectively.

Results – Corn Biomass Yield and N Uptake

At Becker in 2012, 15 days after seeding, all fall-applied alfalfa rates resulted in greater corn biomass than the non-fertilized check, and corn biomass following the highest alfalfa application rate was similar to the fall-applied manure treatment (Figure 6). Fifteen days after seeding, spring-applied alfalfa treatments did not affect corn biomass, and were similar to the non-fertilized check and spring-applied manure treatments. The highest corn biomass yield occurred with fall-applied alfalfa at 300 kg N/ha and the fall-applied manure at 100 kg N/ha. Corn N uptake following fall-applied alfalfa at 300 kg N/ha was similar to fall-applied manure, and was greater following spring-applied alfalfa at 200 and 300 kg N/ha than spring-applied manure (Figure 6). At 30 days after seeding, corn biomass and N uptake was greater in the spring-applied alfalfa treatment at 300 kg per hectare than the other treatments (Figure 6). At 45 days after seeding, both corn biomass and N uptake were greater in spring-applied alfalfa at 200 and 300 kg per hectare, compared to manure treatments and the non-fertilized check (Figure 6).

In 2013 at Becker, at 15 days after seeding, corn biomass following fall-applied alfalfa at 200 and 300 kg N/ha was greater than all other fall treatments and the spring-applied manure treatment, though corn N uptake was similar among all fall- and spring-applied alfalfa treatments (Figure 7). At 30 days after seeding, a similar trend was observed for fall-applied treatments, but corn biomass following spring-applied alfalfa at 200 and 300 kg N/ha and manure was among the greatest of all treatments (Figure 7). At 30 days after seeding, corn N uptake was greater following spring-applied alfalfa at 200 and 300 kg N/ha than all other treatments. Corn biomass and N uptake 45 days after seeding was generally greatest following fall- and spring-applied alfalfa at 300 kg N/ha (Figure 7).

At Lamberton in 2012, corn biomass 15 days after seeding was greater under the spring- and fall-applied manure treatments than alfalfa treatments (Figure 8). At 30 and 45 days after seeding, corn biomass yields following spring-applied alfalfa at 300 kg N/ha was similar to both manure treatments (Figure 8). At all sampling times, corn biomass yield of the non-fertilized check was not consistently different from the fall-applied alfalfa treatments. Corn N uptake response to treatments was similar to that for biomass.

At Lamberton 2013, treatments only affected corn biomass yield at 15 days after seeding, where corn biomass was greatest following both manure treatments, and was similar among all alfalfa treatments and the non-fertilized check (Figure 9). Similar trends were observed in plant N uptake.

Results – Plant-available N

In both years at Becker, plant available N levels at the spring baseline sampling were greatest following fall-applied alfalfa at 300 kg N/ha compared to all other treatments (Figures 10 and 11). At 15 days after seeding, the fall- and spring-applied alfalfa at 300 kg N/ha treatments were consistently among those with the greatest plant-available N. Plant-available N levels were generally similar following all treatments 30 and 45 days after seeding (Figures 10 and 11).

The spring and fall manure treatments were not consistently different than the unfertilized check.

At Lamberton, few differences in plant-available N among treatments was observed in 2012, though plant-available N at harvest following spring-applied alfalfa at 300 kg N/ha was greater than all other treatments (Figure 12). At Lamberton in 2013, plant-available N at the spring baseline sampling was greatest following fall-applied alfalfa at 200 and 300 kg N/ha, and fall-applied manure (Figure 13). Plant-available N 15 and 45 days after seeding was similar among all treatments, and at 30 days after seeding and at harvest was generally greatest following all spring-applied alfalfa treatments (Figure 13). Plant-available N following treatments was highly variable among treatments across sampling dates, suggesting that monitoring soil extractable N levels is not a reliable method for measuring treatment effects on nutrient availability.

Conclusions

Does alfalfa mulch have a positive effect on corn grain yields as compared to no fertilizer? At the Becker site, the spring-applied alfalfa treatments performed better than the check in 2012 and in 2013, and corn yields following both the spring- and fall-applied alfalfa were greater than the non-fertilized check. However, at the Lamberton site, corn yields following alfalfa treatments were not greater than non-fertilized check yields.

Can alfalfa mulch produce corn grain yields similar to manure? Based on our results at the Becker site, generally we found that alfalfa applied at 300 kg N/ha resulted in corn yields similar to those following manure treatments. It would appear that alfalfa mulch does have the potential to perform similarly to manure fertilizer.

Did fall-applied and spring-applied alfalfa mulch differ in their effects on corn grain yield? In 2012 at Becker and Lamberton, spring-applied alfalfa produced greater yields than fall-applied alfalfa. The fate of alfalfa mulch in fall may have been influenced by the presence or absence of live plants. Rasse et al. (1999) reported that in bare fallow soils much of the N mineralized from alfalfa herbage was leached from the upper soil profile.

Does alfalfa mulch affect available soil N and early season corn growth? High rates of alfalfa mulch applied in the spring increased corn biomass compared to the non-fertilized check at Becker, which had sandy soils and low available N levels, but not consistently at Lamberton, where soil nutrient levels were generally high. Where differences in plant-available N were observed, N levels were generally greatest following the high rate of fall-applied alfalfa early in the season, and greatest following the high rate of spring-applied alfalfa later in the season. These results imply that fall-applied alfalfa-N was depleted by the crop early in the season or lost from the system, and that spring-applied alfalfa-N took time to be mineralized to plant-available forms, and was not available to the corn crop until later in the growing season. At Becker, early season treatment effects on corn biomass yield and N uptake were not always transferable to corn grain yield.

Outreach

Our team communicated our research results to farmers, researchers, and agricultural professionals at the state, regional and national level. Graduate student Laura Fernandez demonstrated her field plots at the Organic Field Day in Lamberton, MN on July 11, 2012. She gave a presentation titled "Evaluating Alfalfa Mulch as a Nitrogen Source for Corn Production" at the Soil Science Society of America's Annual Meeting on October 22, 2012 in Cincinnati, OH. Laura also presented research results at the 2013 Midwest Organic and Sustainable Education Service's Organic Conference in La Crosse, WI. On March 31, 2015, Kristine Moncada presented the project's research results at the Southern Minnesota Organic Crops Day in Owatonna, MN.

Figures

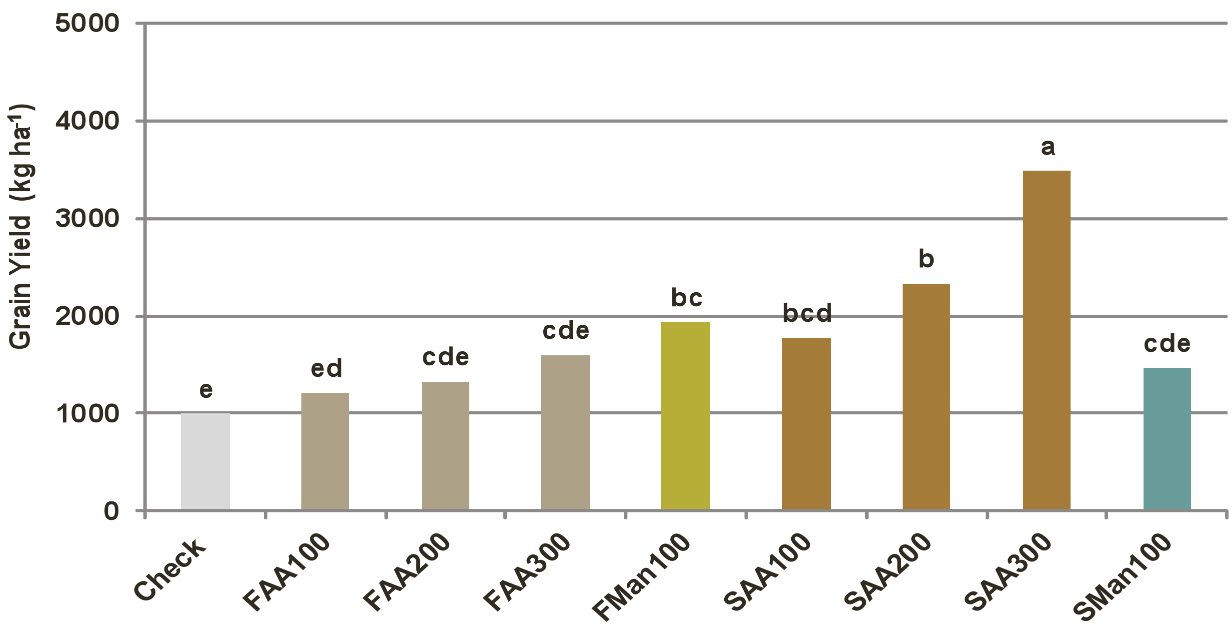

Figure 2. Grain yield for corn growing season 2012 at Becker. Different letters indicates significant differences at P<0.05.

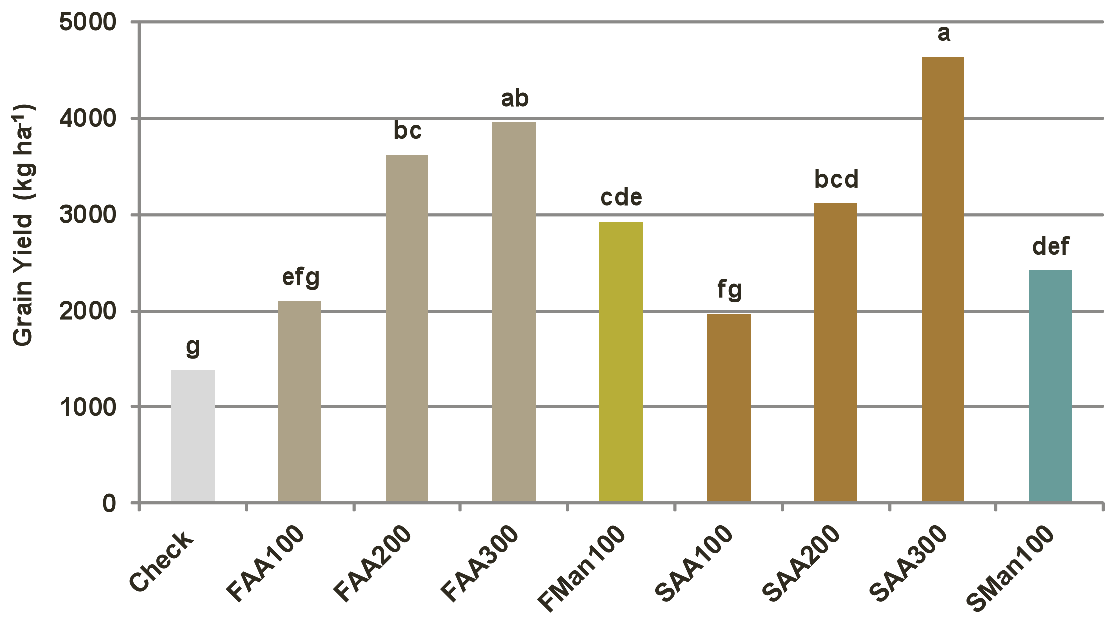

Figure 3. Grain yield for corn growing season 2013 at Becker. Different letters indicates significant differences at P<0.05.

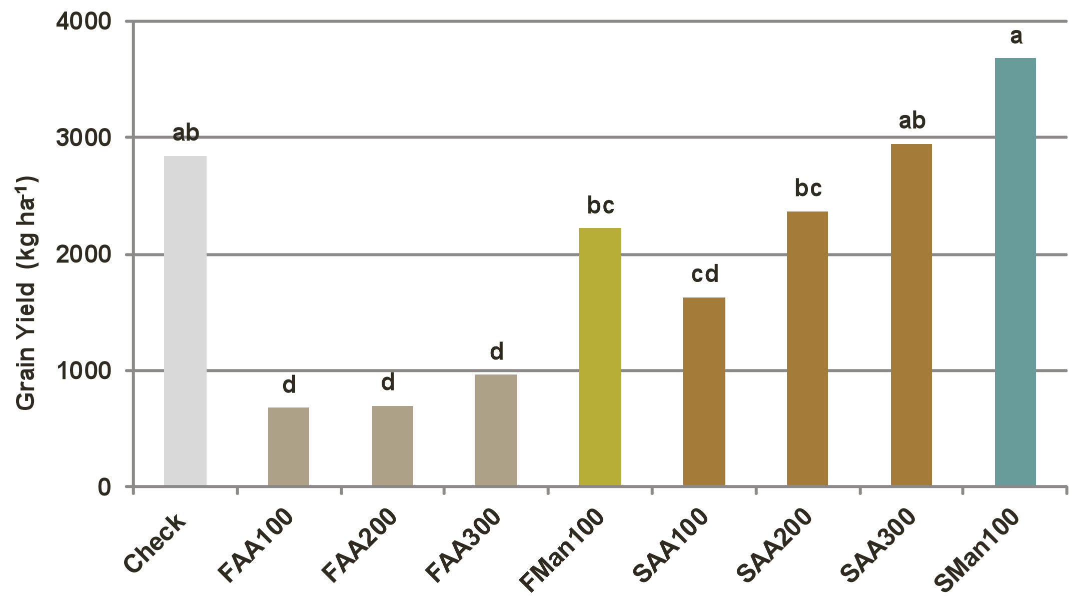

Figure 4. Grain yield for corn growing season 2012 at Lamberton. Different letters indicates significant differences at P<0.05.

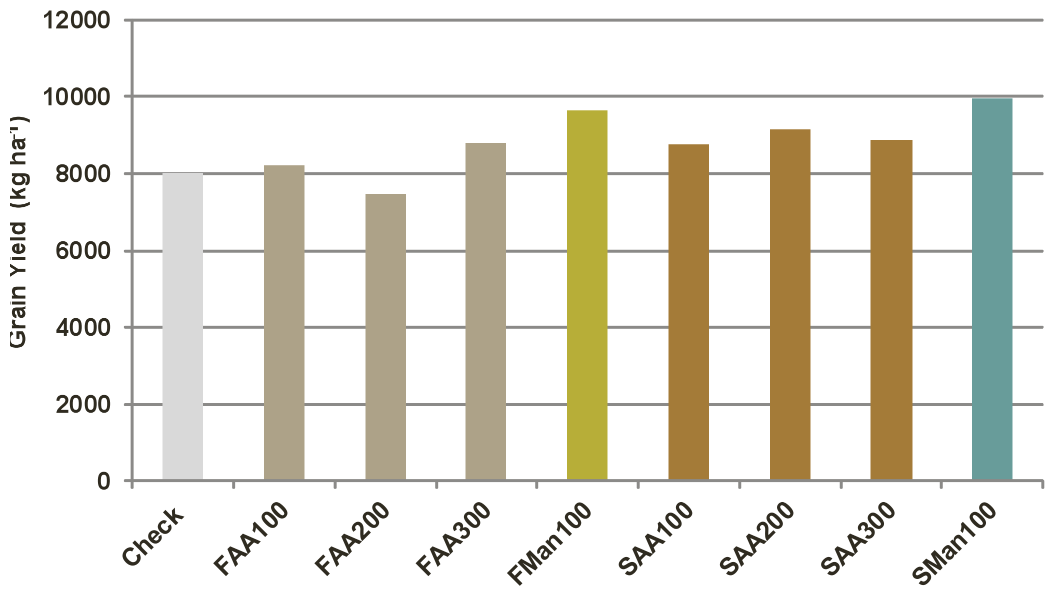

Figure 5. Grain yield for corn growing season 2013 at Lamberton. Different letters indicates significant differences at P<0.05.

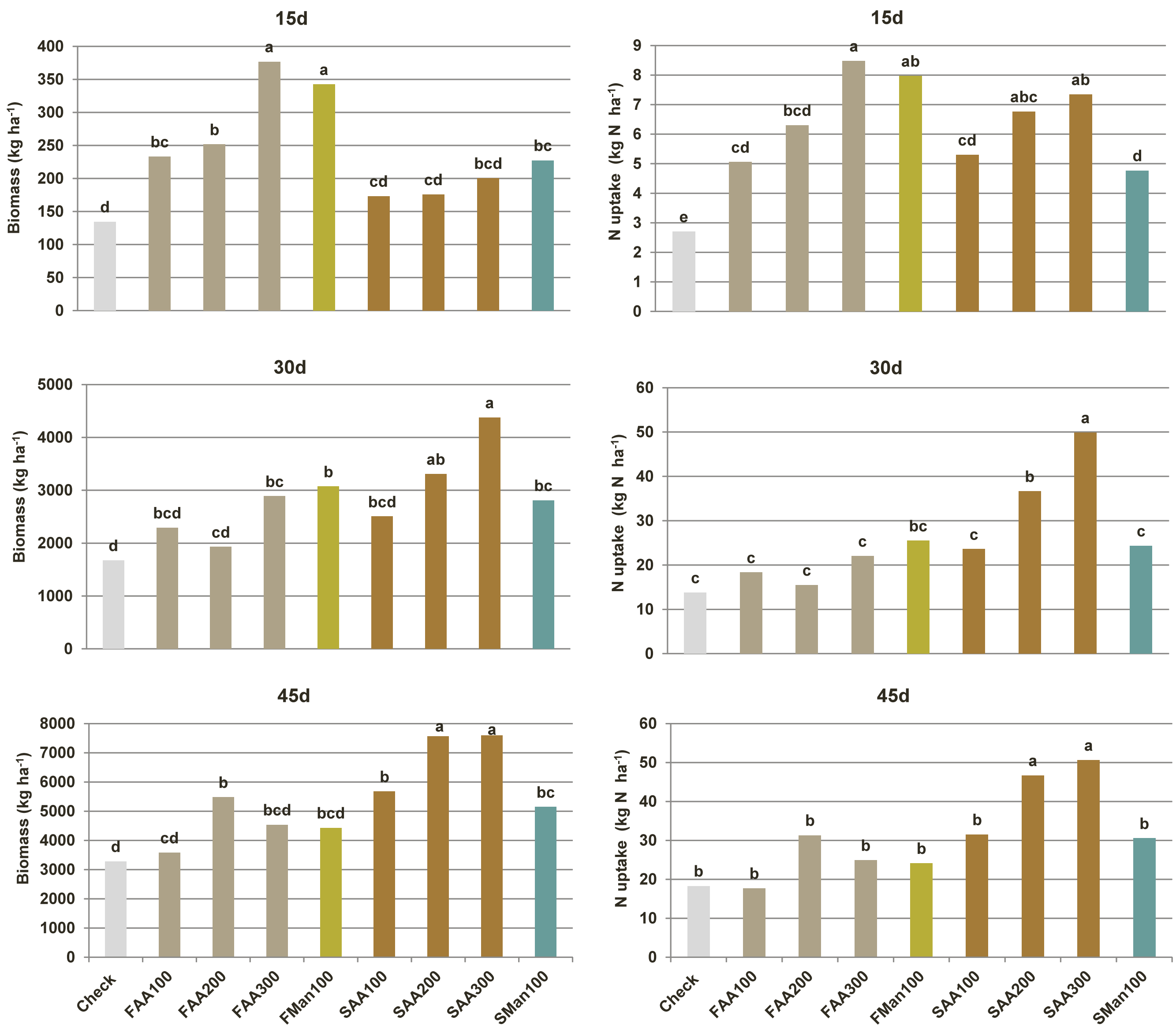

Figure 6. Corn biomass and plant N uptake for 2012 growing season at Becker. Different letters indicates significant differences at P<0.05.

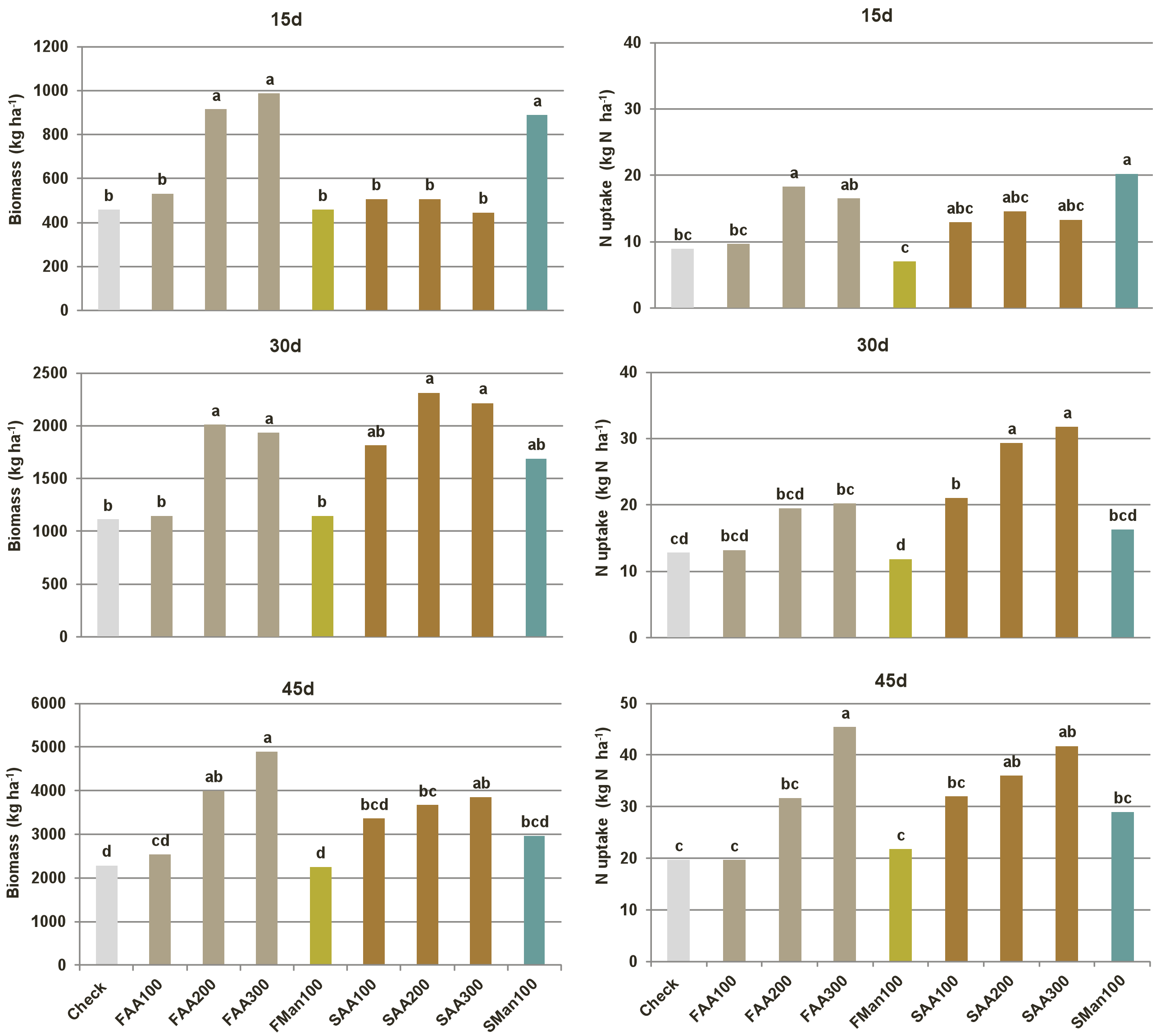

Figure 7. Corn biomass and plant N uptake for 2013 growing season at Becker. Different letters indicates significant differences at P<0.05.

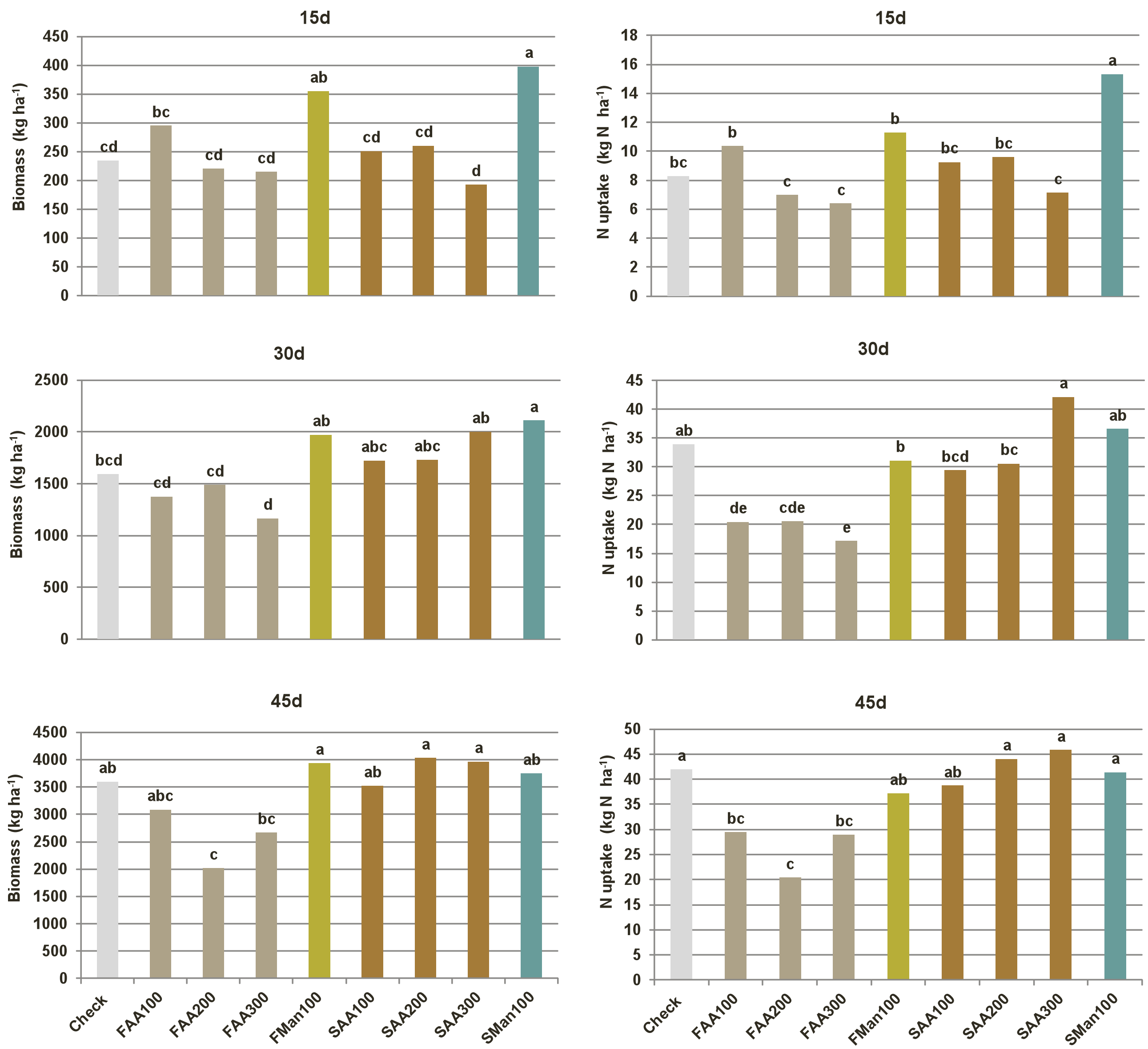

Figure 8. Corn biomass and plant N uptake for 2012 growing season at Lamberton. Different letters indicates significant differences at P<0.05.

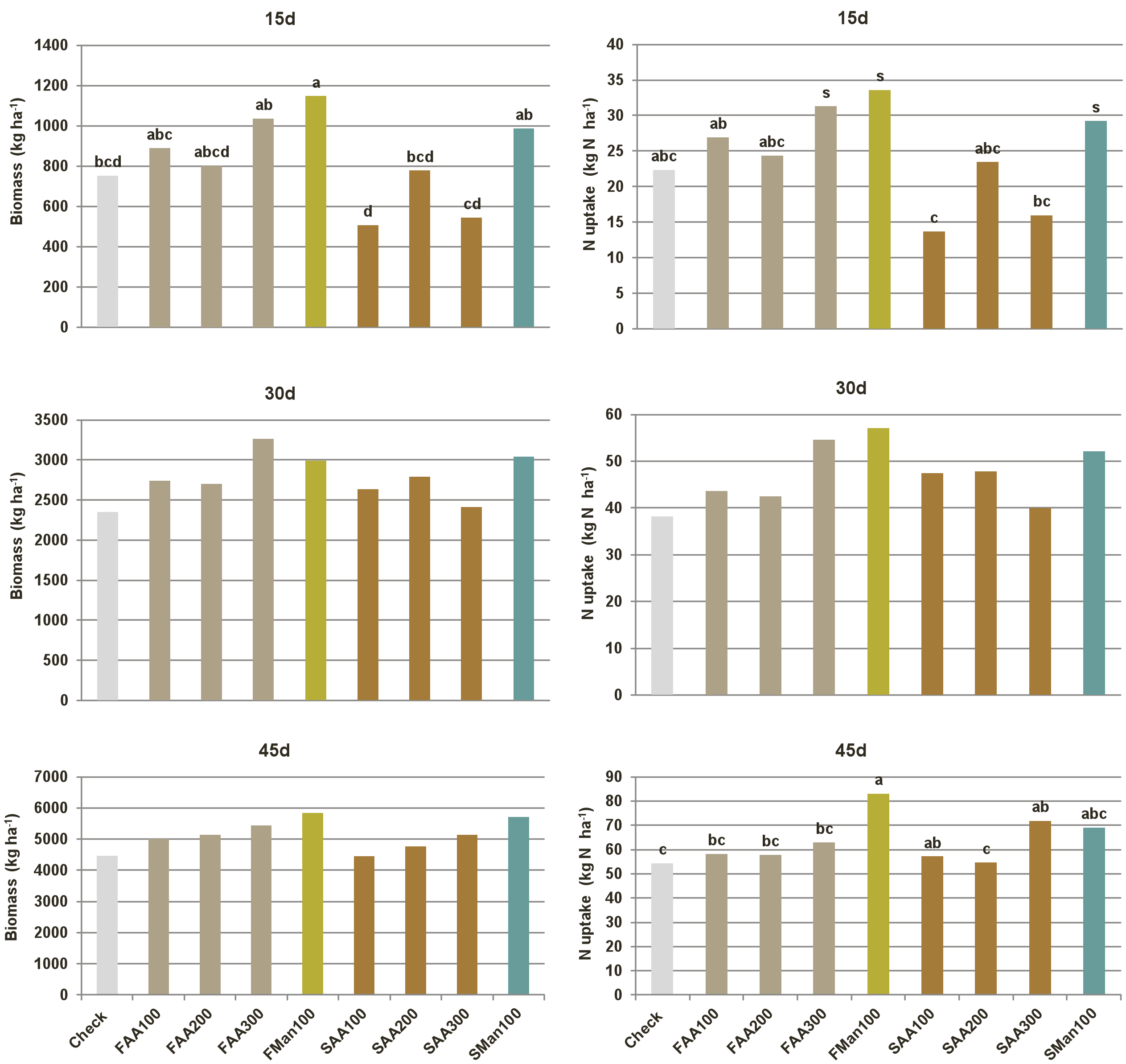

Figure 9. Corn biomass and plant N uptake for 2013 growing season at Lamberton. Different letters indicates significant differences at P<0.05. At 45d differences in N uptake were significant a P<0.10.

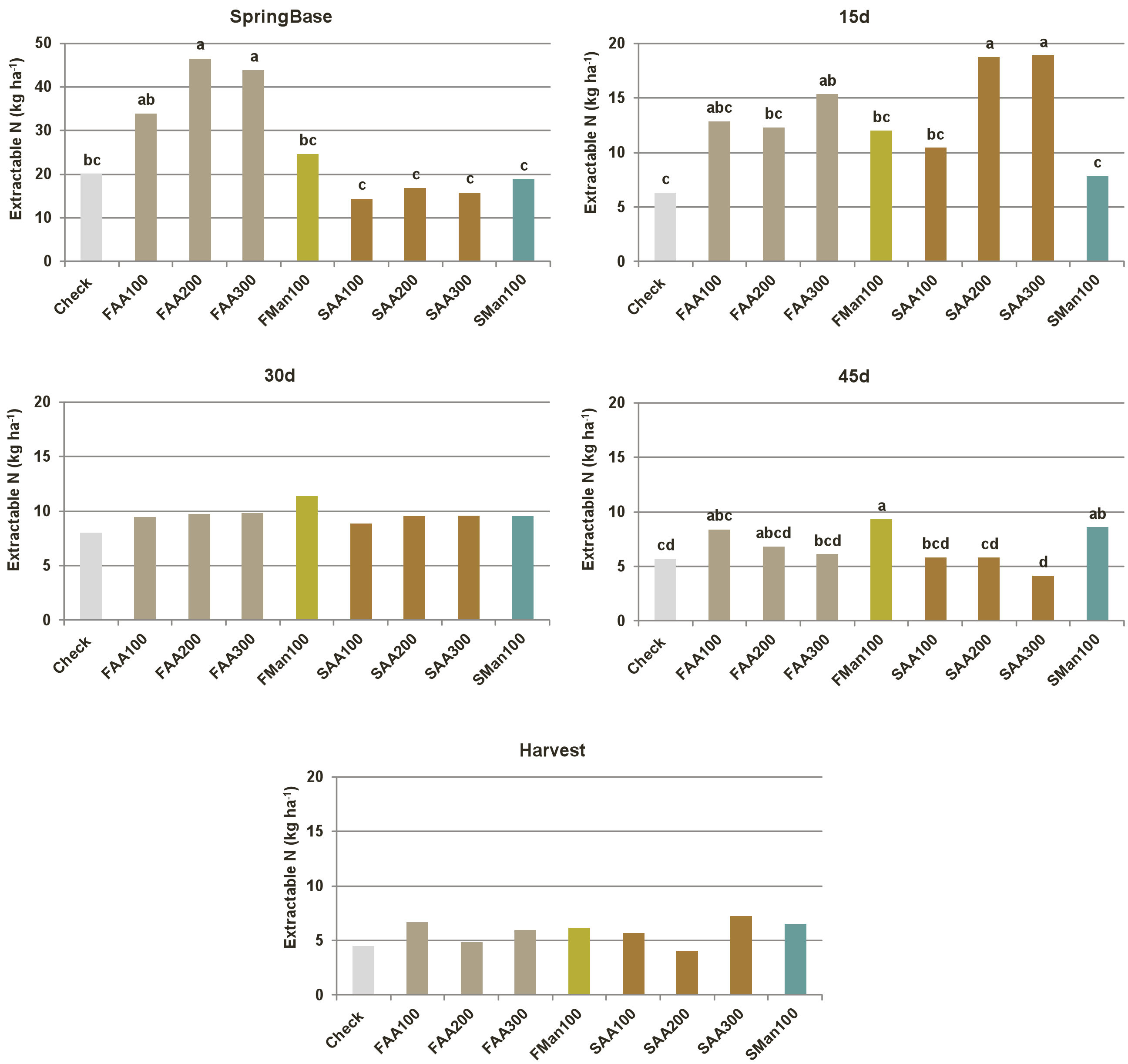

Figure 10. Soil extractable N at 0-31 cm for 2012 growing season at Becker. Different letters indicates significant differences at P<0.05.

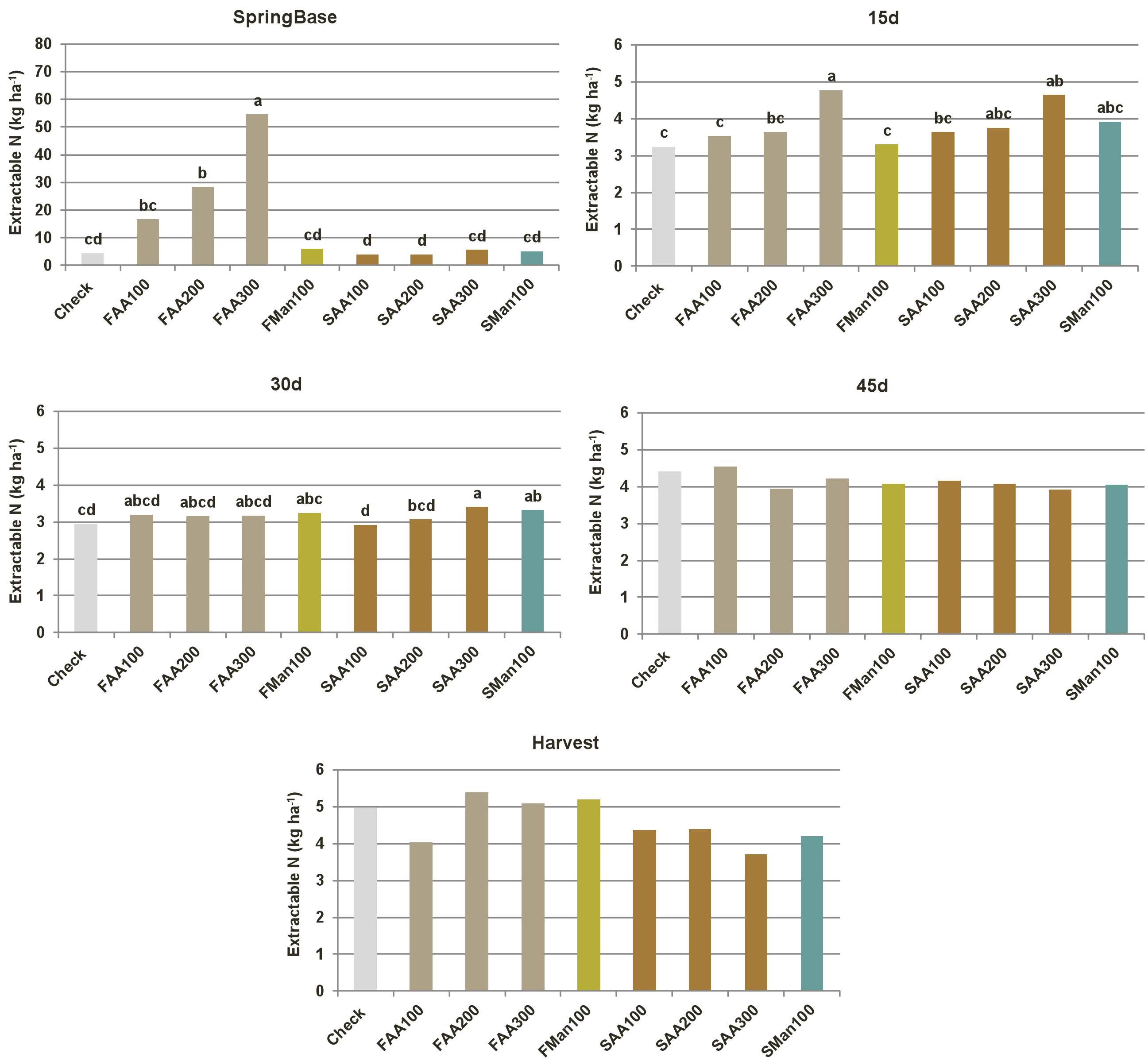

Figure 11. Soil extractable N at 0-31 cm for 2013 growing season at Becker. Different letters indicates significant differences at P<0.05.

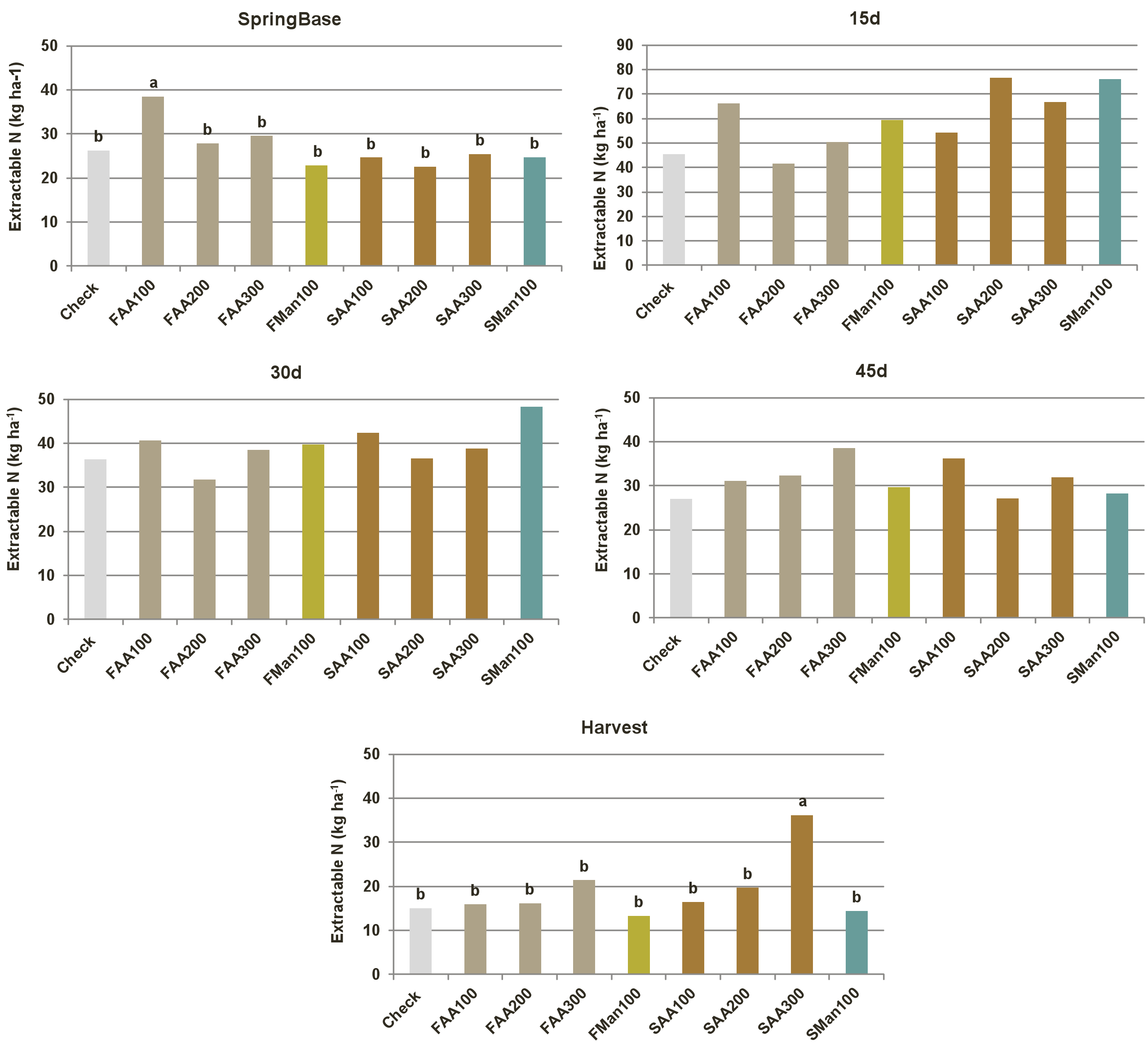

Figure 12. Soil extractable N at 0-31 cm for 2012 growing season at Lamberton. Different letters indicates significant differences at P<0.05.

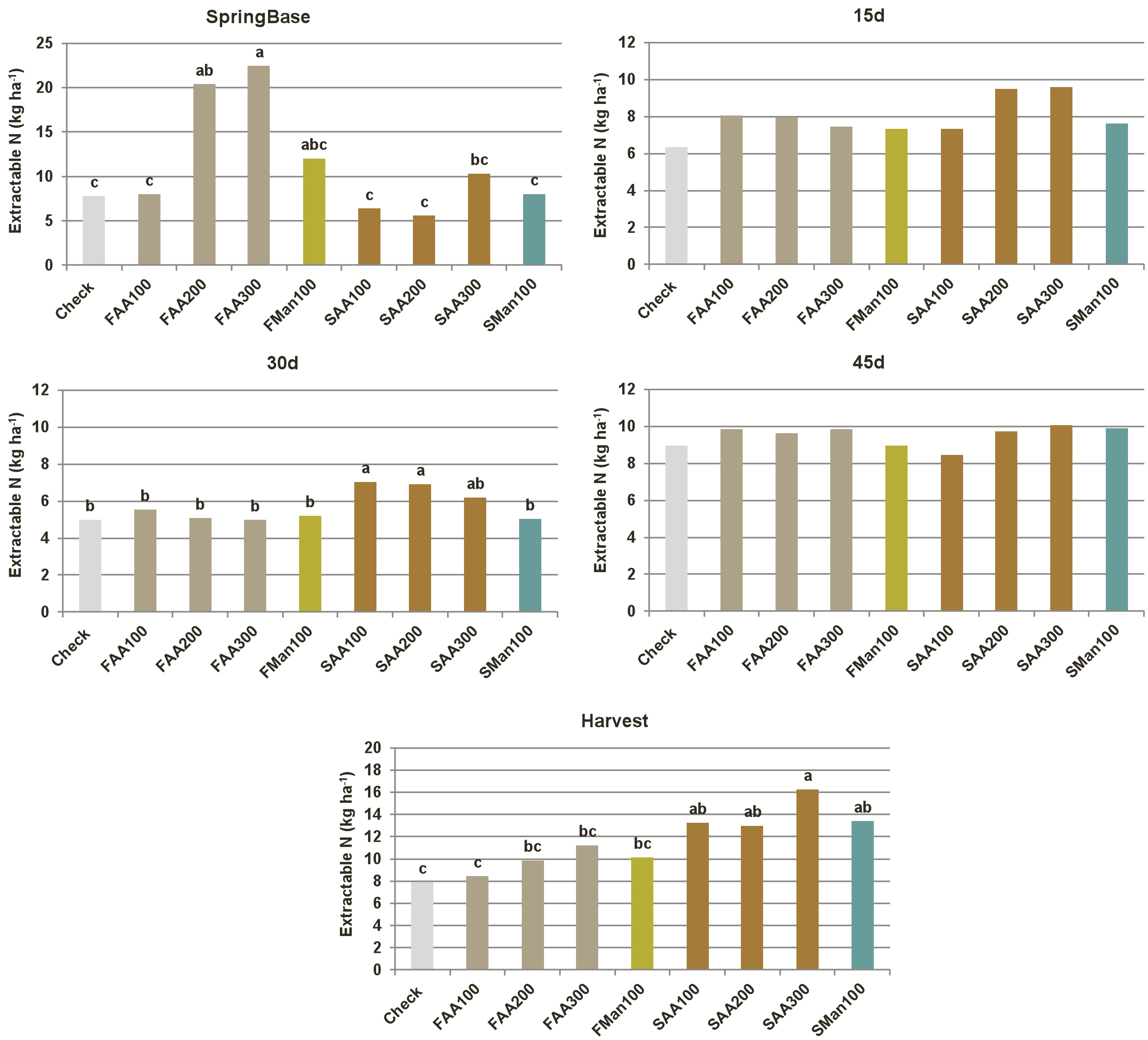

Figure 13. Soil extractable N at 0-31 cm for 2013 growing season at Lamberton. Different letters indicates significant differences at P<0.05, except at Springbase which P values<0.10

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