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Black Plastic Mulch Improved the Uptake of ^{15}Nitrogen from Inorganic Fertilizer and Organic Prunings in Summer-bearing Red Raspberry

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Red raspberry plants (*Rubus idaeus* L.) take up fertilizer N in spring when primocanes and floricanes are growing (Rempel et al., 2004). In irrigated red raspberry fields, soil nitrogen (N) is most available when the soil is warm and moist in mid- to late-summer and is less available when plants are beginning growth and development in the spring (Rempel et al., 2004). The application of surface mulches may result in higher or lower soil temperatures and soil moisture and thus may increase or decrease mineralization and soil available N in spring. Ellert and Bettany (1992) suggested that management-induced shifts in temperature and moisture levels may beneficially influence the synchronization of nutrient mineralization and uptake. Altered soil temperature and moisture could also change the availability of the N in plant residues that are applied in late summer or fall. Mulches can also limit soil erosion, control weeds, and increase yield and quality in potato (Ruiz et al., 1999).

Mulch can include a wide variety of ground covers such as plastic mulch, plant residues, and cover crops with varying effects. Black plastic mulch can increase soil temperature (Nonnecke and Taber, 1989; Trinka and Pritts, 1992) while plant residues can lower soil temperature (Tarara, 2000). Plastic mulches also can lead to a decrease in leaching of nutrients and a decrease in N volatilization (Percival et al., 1998).

Percival et al. (1998) found mulches to be beneficial for primocane-fruiting raspberry plants in the establishment year, because the mulch modified the root-zone temperature and reduced the risk of drought stress. However, after the establishment year, neither black plastic or straw treatments affected soil temperature or moisture levels, possibly due to shading of the mulch by the more mature canopy of the raspberry plants. Trinka and Pritts (1992) found that straw mulch applied at transplanting enhanced cane number and weight of red raspberry plants during the establishment year and the subsequent season, in addition to increasing yields. A study with micropropagated black raspberry found that hardwood bark mulch was not beneficial to yield or total vegetative growth and fruit weight, in either the establishment year or the following year (Warmund et al, 1995).

The commercial practice of flailing red raspberry prunings in late summer to early autumn and leaving them in the field (Crandall, 1995) may affect the N cycle in raspberry. It is not known how much N this would contribute to a red raspberry planting or how long it would take for N from the prunings to be returned to the plant system. Recovery of ^{15}N from mulched kiwifruit (*Actinidia deliciosa* A. Cher.) prunings that were applied to a grass plot was 9% after 2 years (Ledgard et al., 1992).

We initiated this exploratory study to ascertain the importance of management of the floor of a red raspberry field and prunings on plant nitrogen status. Our objectives were to 1) ascertain if N in flailed raspberry prunings is taken up by the raspberry plant and 2) determine whether black plastic and straw mulch affect the recovery of fall-applied nitrogen (organic or inorganic).

Materials and Methods

A mature 'Meeker' summer-bearing red raspberry planting established in 1993 at the North Willamette Research and Extension Center (NWREC), Oregon State University, Aurora, was used for this study. Plants were established at 0.75 m within rows and 3.0 m between rows and were trained in a hill system. The organic matter content of this Quatama series soil (fine-loamy, mixed, mesic Aqualtic Haploxeralfs) was 3% to 4%. The field received overhead irrigation to supply about 2.5 cm of water per week during the growing season when rainfall was inadequate.

The treatments studied were combinations of nitrogen (N) fertilizer type and mulch. Nitrogen treatments were: 1) floricane "prunings", enriched ^{15}N (average 0.476 atom %) applied to plots at a rate of 600 g dry weight per plant on 30 Nov. 2000, a rate calculated based on typical commercial practice. This was the equivalent of 23.2 g/plant of N; 2) N applied as granular ammonium sulfate, enriched ^{15}N (5.0 atom %, Icon Isotopes, Summit, N.J.) at a rate of 19.3 g/plant of N on 30 Nov. 2000. We attempted to get as similar a rate as possible to the organic treatment (treatment 1). Mulch treatments studied were 1) no surface mulch (bare), 2) wheat straw about 15 cm deep, and 3) black plastic (6 ml polyethylene). The mulch treatments were applied around each plant (hill) and covered the raised bed. Mulches were applied after the above fertilizer treatments on 2 Dec. 2000 and were reapplied in March 2002, as needed.

Enriched ^{15}N prunings were obtained by applying enriched ^{15}N fertilizer (5.0 atom %) to three plants outside of the experimental plot area in May 2000. Dead floricanes were pruned from plants in September 2000 with the prunings saved and analyzed for atom %^{15}N. Prunings were cut into about 10-cm lengths (to simulate flail mowing, as done by commercial growers) before application. In March 2002, unlabeled N fertilizer was applied at a rate of 40 kg·ha^{-1} of N, a standard commercial practice. All forms of fertilizer were broadcast on the soil surface in the plant row and up to 0.45 m away on either side of the row. All treatment plots were fertilized with 35 kg·ha^{-1} of P and 66 kg·ha^{-1} of K each spring.

Plants were destructively harvested on 10 July 2002. All above-ground growth (crown, primocanes, and floricanes) and a sub-sample of the roots were collected. Dry weight, N, and ^{15}N data were obtained as described previously (Rempel et al., 2004). Soil samples were collected from each treatment plot to a depth of 25 cm on seven dates throughout 2001 (17 Mar., 14 Apr., 13 June, 10 July, 14 Aug., 17 Sept., 12 Dec.) and the gravimetric soil moisture determined. Soil temperature at 0.15 m depth was recorded from April through December 2001 using a Hobo 8K four-channel datalogger (Onset Computer Corp., Bourne, Mass.).

A completely randomized experimental design was used. There were three replications of each treatment combination. Each single plant replicate had a plot size of 0.7 m^2. Analysis of variance was performed for fertilizer type and mulch effects using the GLM procedure in SAS (SAS Institute Inc., 1999). Natural log and $\log_{10}$ transformations were performed to address heterogeneity of variance; statistical significance amongst treatments was not affected by transformation. Treatment means were compared using a Fisher's protected least significant difference (LSD) test.

Results and Discussion

Mulch treatment had a significant effect on plant recovery of ^{15}N, nitrogen derived from the fertilizer (NDFF) and percent NDFF in red raspberry plants. There was no effect of N source for these variables. There was no interaction between type of fertilizer and mulch on any plant variable measured. Thus, the data presented in Fig. 1 are pooled across source of fertilizer N.

The NDFF in the above-ground plant in July 2002, 1.5 years after fertilizer application averaged 0.57 g/plant in bare plots. This value is lower than the 1.5 g/plant NDFF reported

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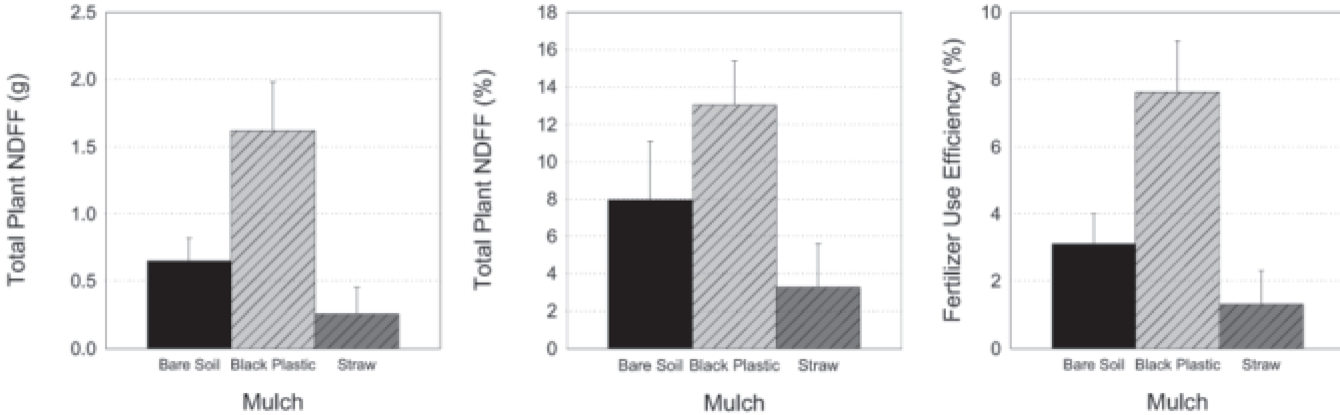

Fig. 1. The effect of mulch treatment on total plant nitrogen derived from the fertilizer (NDFF), percent NDFF, and fertilizer use efficiency (recovery) in 'Meeker' red raspberry 1.5 years after application of ^{15}N-fertilizer granular or ^{15}N-prunings (averaged over N source; n = 6).

by Rempel et al., (2004) from above-ground 'Meeker' red raspberry sampled from an adjacent planting in July 2002 after granular fertilization with 18 g/plant of N in March 2001. This low recovery is to be expected, since spring N applications are generally more readily used than fall N applications in perennial crop systems (e.g., Aguirre et al., 2001). In addition, due to the restraints of applying a typical commercial rate of prunings and thus a low amount of organic and comparable inorganic N, recovery 1.5 years later was expected to be low. Percent NDFF in bare plots averaged 8% (Fig. 1) compared to 13% NDFF reported by Rempel et al. (2004). Recovery of ^{15}N was not affected by whether the N applied was in an organic form (prunings) or inorganic form (granular). The percent of ^{15}N in the plant 1.5 years after application averaged 2.6% for the prunings and 3.6% for the granular fertilizer in bare plots ($p = 0.88$). However, mulch had a significant effect on fertilizer recovery ($p = 0.02$) with black plastic doubling recovery to 7.6% whereas straw mulch reduced recovery to 0.9% (Fig. 1). Mulch had a similar effect on total plant NDFF ($p = 0.049$) and percent NDFF ($p = 0.02$; Fig. 1). Our findings support those of Ledgard et al. (1992) that recovery from prunings is small.

Straw mulch increased soil moisture in summer through mid-September 2001 relative to bare and black plastic plots (Fig. 2). A surface residue of straw can increase the amount of stored precipitation in a field by 2-fold (Unger et al., 1988). Percival et al. (1998) found that black plastic mulch increased soil moisture in 'Heritage' red raspberry. However, in their study drip irrigation was used under the mulch whereas we used overhead irrigation. Black plastic mulch increased soil temperature mostly from September to November 2001 compared to bare plots whereas straw tended to keep the soil cooler (Fig. 3) agreeing with the findings of others (Nonnecke and Taber, 1989; Tarara, 2000; Trinka and Pritts, 1992). Dong et al. (2001) found higher soil temperatures increased the rate of ^{15}N uptake in apple.

In the black plastic treatments we would expect the relatively dry soil and warmer temperatures to have decreased the amount of N leached and increased the incorporation of fertilizer N into organic matter. Percival et al. (1998) noted that nitrate levels were higher in red raspberry soils with plastic mulch than in those without plastic mulch. Rempel et al. (2004) also speculated that loss of soil nitrate in bare red raspberry plots occurred as a result of plant uptake and irrigation driven leaching; there was no nitrate present by December after spring fertilization.

Although our fertilizer was applied in the fall, we would expect most of the uptake to have occurred the following spring (Rempel et al., 2004). With less leaching in the black plastic mulched plots more would have been available the following spring compared to bare plots. In contrast, more N would have likely been immobilized into the organic fraction in straw mulched plots, due to a relatively high C to N ratio (about 200:1). The straw apparently did not release much of the immobilized ^{15}N within the 1.5 years of this study. The cooler soil temperatures in the straw mulched plots would have reduced mineralization. Ledgard et al. (1992) concluded that most of the fertilizer N remained in stable humus forms. Although this N may be released over the long term, little appears to have been mineralized for the duration of this study.

There was no effect of type of fertilizer or mulch on plant dry weight (data not shown). We may have observed differences amongst treatments if the study had lasted longer, as suggested by Rempel et al. (2004).

Our findings show that the practice of flailing red raspberry cane prunings in late summer does return N to the plant system within 1.5 years. In fact, the organic form of N in the clippings was taken up as efficiently as a granular, inorganic form of N applied at the same time. Surface mulches did affect the uptake of fertilizer N with black plastic increasing recovery of N from the clippings to 7.6%. Thus, planting floor management and its potential impact on plant N status is important and should not be overlooked.

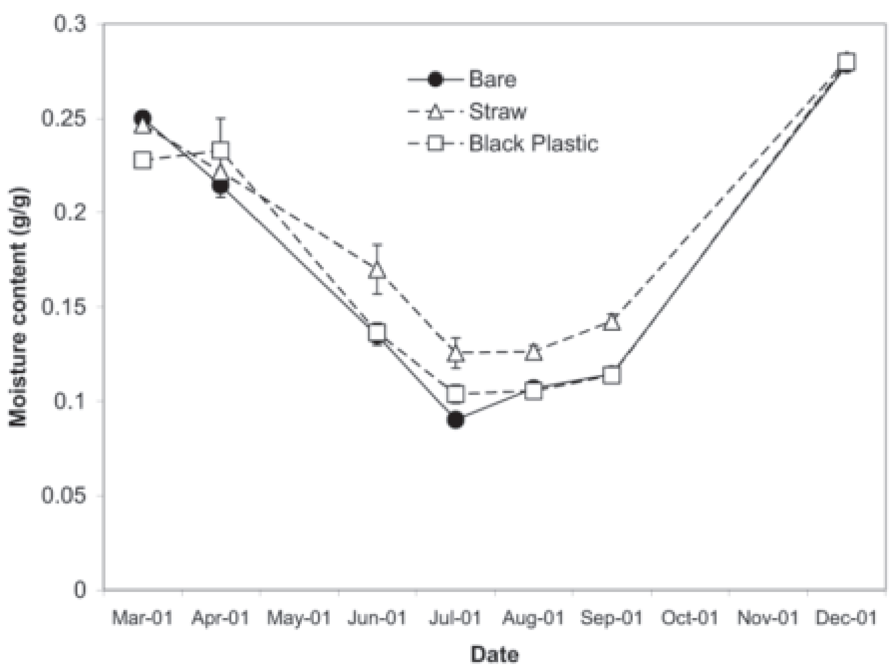

Fig. 2. The effect of surface mulch on soil moisture content from March to December 2001.

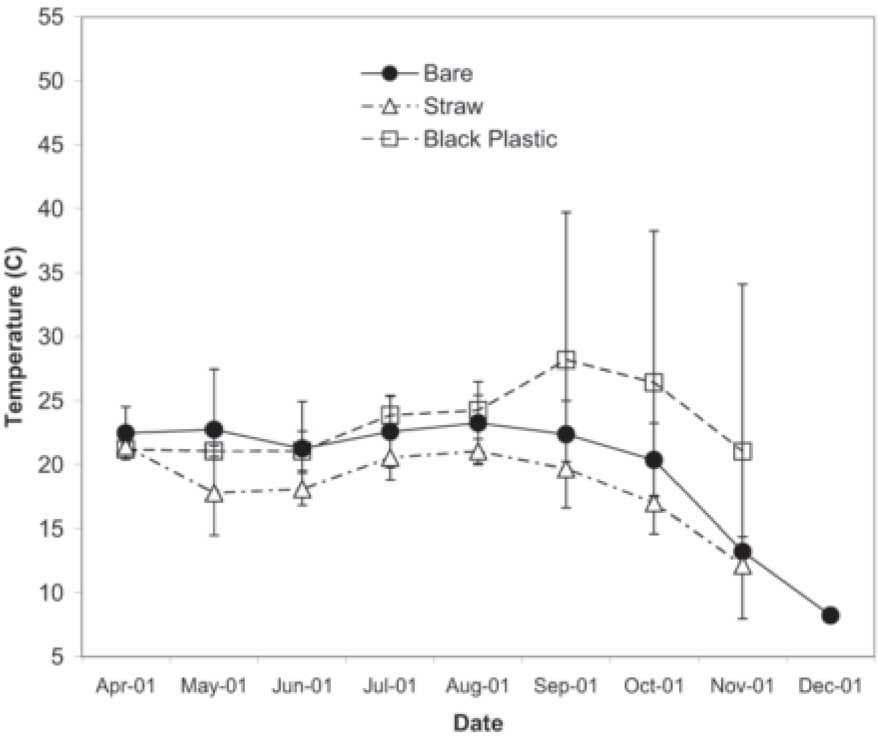

Fig. 3. The effect of surface mulch on soil temperature at 15 cm from March to December 2001.

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