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Planting date and in-row plant spacing effects on growth and yield of cabbage under plastic mulch

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ABSTRACT

Florida is ranked third in total cabbage production in the U.S. and it is traditionally grown on bare ground with subirrigation. The use of plastic mulch and drip irrigation is widespread for other vegetable crops and can enhance water and fertilizer use efficiency and yield. The objective of the study was to evaluate plant growth, yield and head quality traits of cabbage using three plant populations and four planting dates on a plastic mulch system. Cabbage was transplanted in mid September (SEP), mid October (OCT), early November (NOV), and early December (DEC) in the 2013–14 and 2014–15 growing seasons, spanning the entire planting season for commercial operations in northeast Florida. There was no interaction among planting dates and plant populations for total and marketable yields or biomass. For both seasons, the SEP and OCT plantings showed a faster growth rate than NOV and DEC during the first 70 days after transplanting; however, differences in total biomass accumulation were only seen in 2013–14. Biomass decreased quadratically in 2013–14 with an increase in in-row spacing. Average marketable yield for both years was 62.7, 60.5, 46.2, and 58.6 Mg ha^{-1} for SEP, OCT, NOV and DEC, respectively. As plant population decreased, marketable yield increased linearly in 2013–14 while no differences were seen in marketable yield among plant population treatments during 2014–15 season. Plant growth rate and yield were correlated to growing season average air temperature and solar radiation. The SEP, OCT and DEC planting dates benefited from more favorable weather conditions, while low air temperatures and reduced solar radiation had a negative effected on cabbage yield for the NOV planting.

1. Introduction

Cabbage (*Brassica oleracea* var. *capitata)* production in Florida is traditionally grown on bareground with subirrigation. Subirrigation relies on large amounts of water to raise the water table for the purpose of irrigating crops. The shallow water table and the sandy soils commonly found in Florida favor this type of production system. However, the non-uniform distribution of soil moisture across fields and the offsite movement of soluble nutrients during large rainfall events increase the potential for reductions in crop yield. Growers have estimated that about 30% of the potential production under subirrigation does not reach marketable size and or quality.

Although in some vegetable production regions of south Florida the use of plastic mulch is combined with subirrigation, the use of drip irrigation instead of subirrigation can drastically reduce water use. Drip irrigation applies frequent, small volumes of water to the root zone, thereby enhancing soil moisture distribution and irrigation water use efficiency. The benefits provided by plastic mulch are the maintenance of soil moisture in the raised bed, potential reduction in nutrient leaching (Romic et al., 2003), decrease in weed competition (Lamont, 1993), and potential increase in plant population per area for some crops (Barrett et al., 2015). Plastic mulch and drip irrigation has been successfully used in several horticultural crops and significant increases in marketable yield have been observed for eggplant, muskmelon, peppers, cucumbers, summer squash (Locascio, 2005), okra (Tiwari et al., 1998), watermelons, tomato (Shrivastava et al., 1994), bell pepper (Borosic et al., 1998), and sweet potato (Laurie et al., 2015) grown with a plasticulture system. The use of plastic mulch and drip irrigation in cabbage production resulted in a 70% yield increase when compared to a traditional furrow irrigation system (Tiwari et al., 2003). In addition, the use of drip irrigation as an alternative to furrow irrigation, can reduce the incidence of soil pathogens (Xie et al., 1999) and facilitate nutrient management.

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In Northeast Florida, cabbage is commonly planted between the months of September and January, which exposes the crop to a wide range of weather conditions from plant establishment through harvest. Air temperature and solar radiation are key factors for cabbage growth and yield. Cabbage thrives best under cool weather conditions). The air temperature range for optimum plant development is between 16 °C (Criddle et al., 1997) and 20 °C (Hara and Sonoda, 1982). Air temperatures above and below this point tend to slow the rate of growth. In addition, cabbage head development is influenced by the availability of sunlight, especially during the early growth and head formation stages. Plant growth was increased during a growing season with higher levels of solar radiation (de Moel and Everaarts, 1990). While a reduction in solar radiation availability by 66% significantly reduced cabbage yields (Hara et al., 1981; Hara and Sonoda, 1981).

Staggering crop planting dates is a strategy commonly used by vegetable growers to maintain a continuous supply of fresh product. Staggering planting dates may also reduce economic risk by avoiding yield losses due to undesirable environmental conditions and by targeting high market price windows. Previous studies of cabbage grown on bare ground in northern states found that planting date significantly impacted marketable yield (de Moel and Everaarts, 1990; Kleinhenz and Wszelaki, 2003; Orzolek et al., 2000; Sundstrom and Story, 1984; Wszelaki and Kleinhenz, 2003). However, no previous research has investigated the use of plasticulture throughout the entire range of cabbage planting dates for subtropical latitudes, or evaluated production as correlated to the corresponding environmental conditions.

The use of a high plant population is a strategy to increase yield per area and has been used in other brassicas such as broccoli (*Brassica oleracea* var. *italica*) and cauliflower (*Brassica oleracea* var. *botrytis*) (Dixon, 2006). Low cabbage marketable yields caused by a reduction in average head size when using high plant populations can be minimized by extending the growth period (de Moel and Everaarts, 1990) and through a reduction in competition for light and nutrients. However, extending the growing period is not always an option for Florida because of the variability in weather conditions such as high air temperatures and excessive rainfall which can compromise cabbage quality. Halsey et al. (1966) suggested that marketable cabbage yield was higher under Florida conditions when in-row plant spacing was increased from 23 to 30 cm for bare ground production. Barrett et al. (2015) evaluated plant population treatments of cabbage under plastic mulch using different arrangements of in-row plant spacing and number of rows per bed. The study showed that marketable yield was maximized using three or four rows of cabbage per 1.2 m bed with in-row spacings between 25 and 35 cm. The objectives of this study were to evaluate cabbage plant growth, yield and head quality traits from four planting dates with high plant populations using a plastic mulch and drip irrigation system. This research intends to provide information for making management decisions with regard to plant population and planting dates for cabbage production in subtropical environment.

2. Material and methods

Field experiments were carried out at the University of Florida, Hastings Agricultural Extension Center in Hastings, FL (29.69 N; −81.44 W) during the 2013–14 and 2014–15 growing seasons. The soil is characterized as a placid fine sand: sandy, siliceous, hyperthermic, typic, humaquepts (Readle, 1983). Four rows of cabbage was grown on 1.2 m wide raised beds and the distance between bed centers was 2 m (Barrett et al., 2015). Beds were covered with black plastic mulch (1.8 m width, 1.25 mm thickness, VIF film, Polygro, LLC. Safety Harbor, FL) and two drip tapes spaced 0.6 m apart (Aqua-Traxx model EA5081222, 16 mm diameter, 0.3 m emitter spacing, emitter flow of 0.5 L h^{-1} at 55 kPa, Toro Agricultural Irrigation, El Cajon, CA).

A granular fertilizer mix of 10N–4.3P–8.3K was incorporated into beds at a rate of 168 kg ha^{-1} of P_2O_5 prior to fumigation. Beds were fumigated (39% dichloropropene, 59.6% chloropicrin) at a rate of 148 kg ha^{-1} prior to drip tape and plastic mulch placement. Pre-plant fertilizer supplied 42%, 100%, and 42% of the total N, P, and K respectively. A total of 157 kg ha^{-1} of N and K_2O were applied in a split application by fertigation through the surface drip tape. The materials used for fertigation were calcium nitrate (15.5N–0P–0K) and muriate potash (0N–0P–50K). There were four fertigation events, one every two weeks starting at two weeks after transplanting. The proportion of N and K_2O applied in each fertigation event was equivalent to 8%, 15%, 20%, and 15% of the total N and K_2O applied to match the growth of the crop.

The treatments were arranged in a split plot design with randomized complete blocks and four replications. Four planting dates were assigned as the main plot factor. Cabbage cv. Bravo was transplanted on 17 September (SEP), 11 October (OCT), 7 November (NOV), and 3 December (DEC) of 2013 for the 2013–14 growing season and 16 September, 9 October, 4 November, and 2 December of 2014 for the 2014–15 growing season. Three plant populations were assigned as the sub-plot factor. The in-row plant spacings used were 25, 30, and 35 cm, resulting in plant populations of 77,500, 64,583, and 55,357 plants·ha^{-1}, respectively. Main plots were 31.8 m long and sub-plots were 10.6 m long. A tractor-mounted hole puncher was used to make four rows of holes, 0.3 m apart on the raised beds.

Biomass: To assess plant growth, two representative plants per treatment were harvested biweekly from transplanting to harvest. The plants were collected from one internal and one external row of the raised beds. Samples were dried at 65 °C until stable weight for subsequent mass measurement.

2.1. Yield

The center six meters of each plot were harvested for yield and head trait data. The first harvest occurred when approximately 50% of the cabbage heads reached 1 kg, while all remaining plants were harvested during a second harvest. Cabbage was harvested by cutting the stem at the soil surface. The heads were weighed before and after the removal of the outer wrapper leaves. Cabbage heads were classified as marketable when trimmed head weight was above 1 kg and unmarketable for head weight below 1 kg. Total cabbage yield was calculated as marketable and unmarketable trimmed heads. A total of 20 cabbage heads (5 per heads per row) per plot were randomly selected for internal quality evaluation. Measurements of cabbage head equatorial and polar diameter, core length, and core base width were recorded. Cabbage heads were treated as a sphere for the head volume calculation and cores were treated as a cone for the volume calculation, as described by Kleinhenz and Wszelaki (2003). During the 2014–15 season, an overhead irrigation system was utilized to improve plant establishment. The weather station number 270 from Florida Automated Weather Network (www.fawn.ifas.ufl.edu) located within 100 m of the experimental site provided air temperature, relative humidity, solar radiation, and wind speed data every 15 min (FAWN, 2015). Growing degree days were calculated by averaging daily maximum and minimum air temperature minus the base temperature of 10 °C (Isenberg et al., 1975).

2.2. Data analysis

An analysis of variance (ANOVA) for each measured variable was conducted for both growing seasons using the GLIMMIX procedure