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FIELD-6709; No. of Pages 8
ARTICLE IN PRESS
Field Crops Research xxx (2016) xxx–xxx
Contents lists available at ScienceDirect
Field Crops Research
journal homepage: www.elsevier.com/locate/fcr

Mulch and planting depth influence potato canopy development, underground morphology, and tuber yield

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ARTICLE INFO

Article history:
Received 31 January 2016
Received in revised form 30 April 2016
Accepted 3 May 2016
Available online xxx

keywords:
Emergence
Harvest index
Stolon
Tuber growth rate
Underground stem

ABSTRACT

The response of potato (*Solanum tuberosum* cv Haryeong) to mulching and different planting depths was evaluated during 2010–2013. Two different plastic mulches, black and clear polyethylene (PE) were compared with the unmulched control and seed tubers were planted at 5-, 10-, 15-, and 20-cm depths in each treatment. The objectives were to determine how mulching and planting depth affected the canopy development, underground morphology, and tuber yield. Early emergence, canopy development and tuber growth rate were improved in the mulched treatment; while delayed or decreased as the depth of planting increased. The number of stems per plant increased as seed pieces were planted closer to the soil surface in two of the four seasons, but was not affected by mulches except for 2012. Stolon length was longest in black mulches, especially on upper part of underground stem, but it was long on lower part of the stem in unmulched potatoes. Percent tuber bearing stolons were increased in the mulches and deep (10–20 cm) planted potatoes. Particularly, on the lower part of underground stem, a higher percentage of tubers were formed irrespective of mulches and planting depth. Harvest index was significantly higher in clear PE mulches in two of the four seasons while it was not affected by planting depth. Mulching potatoes produced higher total and >80 g yields, while varying the depth of planting affected the total yield which was lower in the deepest (20 cm) planted potato.

1. Introduction

Soil mulching which covers the soil at the base of cultivated plants with a layer of protective material (Bégin et al., 2001) has been widely used in Korea for growing crops like potatoes. The benefits of mulching potatoes include saving irrigation water (Singh et al., 2015; Wang and He, 2012), reducing soil erosion (Edwards et al., 2000) and leaching of fertilizer (Bégin et al., 2001), controlling weeds or reducing the dose of herbicide (Bégin et al., 2001; Kasirajan and Ngouajio, 2012), enhancing early growth (Jett, 2012; Zhao et al., 2014) and harvest (Bégin et al., 2001; Kim et al., 1992; Lamont, 2014), and increasing yields (Bégin et al., 2001; Kasirajan and Ngouajio, 2012; Orzolek and Lamont, 2013; Singh et al., 2015; Zhao et al., 2014). The last three have been the main purpose of mulching potatoes in Korea, where the demand for labor-saving crop production is increasing. However, there are controversial reports on the effects of mulch on the emergence, growth and tuber yield, with little or negative effect in some studies (Henninger et al., 1977; Rykbost and Cetas, 1977; Wang et al., 2009; Wang et al., 2011). This variability of potato responses between mulched and conventional practices might be attributed to differences in climatic conditions. Wang et al. (2009) reported the occurrence of low yields due to the poorer soil aeration and high soil temperature associated with mulch. It has been suggested that plastic mulch should be removed early in the regions such as northwest China. Midmore et al. (1986a) showed that mulching did not always ameliorate the adverse effects of high temperature on potato in hot tropics. Soil temperature and moisture has depended on the physical properties of mulch, e.g. thermal conductivity, and their interaction with environmental conditions.

Thoroughly decomposed manure, peat moss, bark chips, sawdust, paper (Bégin et al., 2001), crop residues such as rice (Singh et al., 2015) and barley (Kirchner et al., 2014) straw, and plastic film (Henninger et al., 1977; Kasirajan and Ngouajio, 2012; Zhao et al., 2014) have been used for soil mulch. Although straw mulches were still tested for enhancing yields in a subtropical environment (Singh et al., 2015), reducing PVY incidence in Finland (Kirchner et al., 2014), and controlling tuber blight in USA (Nyankanga et al.,

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http://dx.doi.org/10.1016/j.fcr.2016.05.003
0378-4290/

Please cite this article in press as: Chang, D.C., et al., Mulch and planting depth influence potato canopy development, underground morphology, and tuber yield. Field Crops Res. (2016), http://dx.doi.org/10.1016/j.fcr.2016.05.003

2008), the use of plastic film has increased in agriculture by replacing the traditional crop residues or plant fibers (Bégin et al., 2001; Kasirajan and Ngouajio, 2012). Plastic film such as polyethylene (PE) has been used for soil mulching since the early 1950s throughout the world (Lamont, 2004) and late 1970s in Korea (Kim et al., 1992), because of its better suitability or effectiveness to intensive farming. In order to provide early potatoes with high yield for markets, most of the growers in Korea are using intensive production technology such as PE mulches. Different colored PE mulches are used in different seasons for growing potatoes. During spring and winter, growers use clear PE films to increase soil temperature and to conserve soil moisture. When high temperature and precipitation are prevalent in summer and autumn, black PE films are normally adapted by farmers to control weeds. The alteration in quality (far-red to red ratio) and/or quantity (PAR) of light reflected from different colored mulches affected yield increases (Matheny et al., 1992).

The other benefit of using plastic mulch is the elimination of hilling. However, when planted close to the soil surface under plastic mulch, root growth of emerging plants can be damaged by high temperatures and dry conditions (Kim et al., 1992). Kim et al. (1992) planted Superior, Shepody, and Dejima cultivars at depths of 5-, 10-, and 15-cm under clear PE mulches. There was no significant difference in yield resulting from the planting depths even though plants emerged later and showed higher LAI from the deeper planting depth. There is few published information on how potato crops would respond to plastic mulches with focus on belowground morphology, especially when the PE mulches were combined with planting depth. The reported study evaluated the effects of mulch and planting depth on canopy development, belowground morphology, and tuber yield in spring crop area in Korea.

2. Materials and methods

2.1. Experimental site and design

Experiments were carried out in 2010–2013 to investigate the effect of mulch and depth of planting of potato cv Haryeong (Park et al., 2006) on canopy development, underground morphology, and tuber yield. All experiments were conducted on the Highland Agriculture Research Institute farm (37°77′N, 128°94′E, 20 m elevation) located in Gangneung. Seed tubers were hand-cut into pieces weighing approximately 30–50 g and hand-planted using cone-shaped dibbles at 5-, 10-, 15-, and 20-cm depths into a Bugpyeong coarse loamy over sand (mixed, nonacid, mesic family of Typic Udifluvents) with 30–34 g kg^{-1} organic matter, 5.8–6.4 pH, 0.12–0.28 dS m^{-1} EC, 1170–1490 mg kg^{-1} available P_2O_5, 0.7–1.4 cmol$^+$ kg^{-1} K, 2.0–3.8 cmol$^+$ kg^{-1} Ca, and 0.8–1.1 cmol$^+$ kg^{-1} Mg (Table 1). Planting depth was determined by measuring from the top of the seed piece to the top of the hill (Bohl and Love, 2005; Chang et al., 2014; Pavek and Thornton, 2009).

Each year, the experiment was arranged in a split-plot design with three replications. Mulch treatment served as the main plot and planting depth served as the subplots. Each subplot had three 8–10 m rows with 32–40 plants per row depending on the year. Row width was 80 cm and in-low seed piece spacing was 25 cm. The potatoes were not irrigated and grown under standard practices for potato. Planting dates were March 30, 2010, April 4, 2011, March 22, 2012 and March 19, 2013. The final harvest of plots occurred at 100 days after planting (DAP) in 2010 and 2011, and 110 DAP in 2012 and 2013. Weather conditions during the growing season were monitored by Korea Meteorology Administration (KMA, 2010–2013) located adjacent to the experimental site. Average temperature, daily sunshine hours and precipitation data were 18.3–19.3 °C, 4.7–6.7 h and 261–882 mm (Table 2).

2.2. Growing degree-days, plant emergence, groundcover, and growth analysis

Immediately after planting in each season, temperature (1000-B2N, Veriteq, Canada) and soil humidity (WatchDog 1400, Spectrum Technol., USA) loggers were buried in the seed hill next to seed pieces to record soil temperature and humidity. Temperatures were recorded every hour and 5 °C was selected as base temperature for calculating growing degree-day.

As plants began to emerge, plant number was recorded twice a week in an effort to pinpoint DAP to >80% emergence during each year. Based on the suggestions of Pavek and Thornton (2009), plants were considered emerged when green foliage was seen protruding through the soil surface. During the canopy development, percent groundcover was recorded weekly (2012) or twice a week (2013) beginning 50 DAP using an 80 × 80 cm groundcover grid (Pavek and Thornton, 2009). When groundcover for all treatments reached near 100%, measurements ceased and the data were expressed as days after planting to 50 and 90% groundcover, respectively.

To count stem numbers and calculate percentage of tuber bearing stolons, tuber growth rate (TGR), and harvest index (HI), several hand harvest were conducted between 50 DAP and 90 DAP. In each harvest, stems and stolons from two intact plants were counted and then stolons were separated into tuber bearing and without tubers. The shoots and tubers were oven dried at 85 °C for more than 3 days and then each dry weight was taken. Dry weight in each component was used to calculate TGR (Chang et al., 2011; Gardner et al., 1985) and HI (Zebarth et al., 2006).

$$\mathrm{TGR}(\mathrm{g\,m^{-2}\,day^{-1}}) = (T_2\text{-}T_1)/(t_2\text{-}t_1)$$

$$\mathrm{HI}\,(\%) = \text{tuber dry matter accumulation}/\text{plant dry matter accumulation}$$

where T_1 and T_2 are tuber dry weights in 50 or 60 DAP (t_1) and 71 or 81 DAP (t_2), respectively.

2.3. In-season hand harvests and post harvest measurements

To assess in-season plant development, belowground morphological data were collected at 105 DAP in 2012 and 120 DAP in 2013. Six intact plants from each planting depth were harvested and the vines were removed. Belowground structures from the remaining plants were allowed to air-dry. Belowground stems, soil line to seed piece, were mathematically separated into three zones, lower, middle, and upper. Mean stolon length, tuber number, and tuber weight were determined for each zone.

Five to ten plants from each plot were hand harvested. Each tuber was washed, air-dried, and then graded according to RDA standards into six groups (<30 g, 30–80 g, 80–150 g, 150–250 g, 250–330 g, >330 g). Total tuber yield was determined and then segregated into <80 g and >80 g. Statistical analyses were performed using the SAS system (SAS Institute Inc., Cary, NC, USA). To compare significant means of mulch treatment, LSD values were included on each Table.

3. Results

3.1. Emergence and early canopy development

When soil temperatures were measured during the growing season in 2010, growing degree-days (>5 °C) were higher in plastic mulches than in unmulched (Fig. 1). During 2013, the growing degree-days from clear plastic mulch were also higher, but those of black PE mulches were lower than those of no mulch. The growing degree-day values decreased by 5–6% from 1941 to 1836 in 2011 and 2289–2169 in 2013 as planting depth increased. Until the early