Field Crops Research 223 (2018) 57–65

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Improvements of emergence and tuber yield of potato in a seasonal spring arid region using plastic film mulching only on the ridge

Shu min Liang[a,1], Cai Ren[b,1], Peng jun Wang[c], Xing ting Wang[c], Yan shan Li[a], Fa hai Xu[c], Ying Wang[a], Yan qiong Dai[c], Lei Zhang[a], Xian ping Li[a], Kang Zhan[c], Qiong fen Yang[a,*], Qi jun Sui[a,*]

[a] Industrial Crops Research Institute/Potato Engineering Technology Research Center of Yunnan Province, Yunnan Province Academy of Agricultural Sciences, Kunming 650200, Yunnan, China

[b] College of Grassland and Environment Sciences, Xinjiang Agricultural University, Urumqi 830052, Xinjiang, China

[c] Potato Seeds Research and Development Center, Agricultural Technology Extension Center of Xuan wei, Xuan Wei 655400, Yunnan, China

ARTICLE INFO

Keywords:
Plastic mulching
Emergence
Yields
Potato
Spring drought

ABSTRACT

Potato (*Solanum tuberosum*) is one of the most important economic crops in Yunnan Province (southwest China). However, under rain-fed agricultural conditions, the seeding emergence and yield suffer from seasonal spring drought. In mitigating this problem, field experiments were conducted for 2 years (2015 and 2016) to examine the effectiveness of cultivation patterns for rain-fed potato. Four experiments with different cultivation patterns were carried out: (1) no mulching on ridges and furrows (RFNM-CK), (2) ridge-furrow planting without plastic film mulching after flat planting (RFAF), (3) half mulching only on ridges (RFHM), (4) soil covering after plastic film mulching only on the ridges but not on furrows (RFSM). The temperature of topsoil (0.15 m) was similar among the cultivation patterns. The precipitation and soil conditions were the dominant ecofactors that limited the seedling emergence and yields. RFHM had the best effect on rain harvesting, then improved the topsoil moisture which contributed to good emergence rate and seedling emergence for 14–32 days earlier than CK ($P < 0.05$). Its superiority also resulted in higher plant height, faster accumulation of dry matter and longer period of yield formation, thereby producing the highest tuber yields (8.3–29.4% higher than CK) and economic benefits in both years. Our results from this investigation revealed that RFHM could be an appropriate cultivation mode to increase the emergency and potato productivity in the rain-fed agroecosystem.

1. Introduction

Potato is the world's fourth most important food crop, after rice, wheat, and maize (He et al., 2012). Currently, China is the topmost potato production country (Wei, 2005; Sang et al., 2014). On account of the climate of Yunnan province (southwest China), it is quite suitable for planting potato year-round. So, Yunnan is one of the most potato planting areas, which accounts for 10.1% of the total national yield. Besides, the spring potato accounts for 2/3 yield in this area (Sang et al., 2014). Worldwide, drought is one of the most important environmental stress factors that limits the agricultural production (Si et al., 2012). Similarly, most of the region of Yunnan province is seasonal spring arid and irrigation is not available, which affects spring potato emergency speed and emergency rate, thereby affecting the growth and yield, and also varies greatly in different years. Therefore, water-harvesting and the right selection of soil moisture play important roles in this region (Sang et al., 2014; Mao et al., 2015).

In order to overcome the problem of spring drought, many cultivation modes are being exploited such as rainwater harvesting, ridge pattern, mulching including crop straw and plastic (Zhao et al., 1995; Mzirai and Tumbo, 2010; Wang and He, 2012a). But the difference is quite large and the effect is limited between years. Thus, there is an urgent requirement of a stable, high production and efficient cultivation mode. In other similar arid areas, plastic mulching could improve the temperature of soil, the water content of soil, seedling rate and earlier seedling (Anikwe et al., 2007; Mao et al., 2015; Xue et al., 2014), biomass and tuber yield (Gan et al., 2013; Liu et al., 2014; Li et al., 2016). Therefore mulching was introduced to Yunnan province, by considering of its influence in other regions. However, employing the same methods of muching as followed in other similar arid areas is

* Corresponding authors.
E-mail addresses: yangqiongfen@qq.com (Q.f. Yang), 1073480661@qq.com (Q.j. Sui).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.fcr.2018.03.012
Received 8 December 2017; Received in revised form 11 March 2018; Accepted 15 March 2018
0378-4290/

often caused in lower potato production due to the low emergence in this region. When filling to the gaps, the farming season would be missed, which cause losses for the farmers (Liu et al., 2011; Zhao et al., 2015). In the meantime, few researchers have reported that plastic mulching for the whole growth period could considerably lower the yields because of higher soil temperature in the midsummer (Li et al., 2004; Zhao et al., 2012; Wang and He, 2012b). Based on these considerations, certain measures such as the mulching pattern and mulching position must be tested in this region. Furthermore, the mechanisms of mulching responsible for the improved seedling rate, earlier seedling and yield remain unknown until now (Gan et al., 2013).

On this context, the objectives of the current study were: (1) to evaluate the effects of different cultivation patterns on the temperature and water content of soil during the growth season, (2) how the dynamics of potato emergence could be affected in the absence of mulching and plastic mulching, (3) to determine an appropriate cultivation mode for the maximum yield and economic benefits of rain-fed potato in this seasonal arid area.

2. Materials and methods

2.1. Experimental site

The study was conducted during 2015 and 2016 at Xuanwei (southwest China) which represents a typical rain-fed and spring drought area and has one harvest per year. Years of meteorological data have been briefly described in Table 1 which were obtained from the weather station at the study site.

2.2. Experimental design

Four cultivation patterns were arranged in a randomized block design with three replications in both years (Fig. 1): RFNM (A-CK), ridge-furrow planting without plastic film mulching; RFAF (B), ridge-furrow planting without plastic film mulching after flat planting; RFHM (C), plastic film mulching only on the ridges but not on furrows; RFSM (D), soil covering after plastic film mulching only on the ridges but not on furrows. Wide ridge (1.2 m width, 0.2 m high) with furrow (0.2 m width) were alternatives in the treatments A, B and D. In treatment B, the land was prepared to flat planting, and intertilled to ridge-furrow planting form as in treatment A. In treatment C, wide ridge (0.9 m width, 0.2 m high) with furrow (0.5 m width) were built alternatively during the preparation of land, and the plastic film was removed and transformed to as in treatment A with intertilling. In treatment D, it was intertilled, and the plastic film was not removed. The plastic film was a black transparent polyethylene film with 1.2 m wide and 0.008 mm in thickness. Each block was 5 m long and 4.2 m wide which was seeded at a population density of 51429 plants ha^{-1} (108 plants in each block). The main agronomic management practices are shown in Table 2.

Table 1
Brief description of experimental field at Xuanwei, Yunnan Province, China.

Items	Value	Annotation
Location	26°5′ N, 104°4′ E	
Altitude (m)	1960	
Land surface	Flat farmland	
Effective accumulated temperature (°C day)	2148.6	4.4–30 °C
Frost-free period (d)	231	
Average air temperature (°C)	13.4	The average of 1951–2013
Annual precipitation (mm)	710.9	More than 60% occurring from June to September
Annual pan evaporation (mm)	> 1200	
Percentage of rainfall in seedling stage (%)	8	
Sunshine hours (h)	> 1800	
Major crops	Potato, corn	

2.3. Weather and soil measurement

Weather data were collected from the weather station at the experimental site, and an effective rainfall could be defined as when the precipitation is ≥5 mm (Zhao et al., 2012). In this site, it was clayey soil, where the soil infiltration rate was 0.026 mm s^{-1} (0–60 cm), soil bulk density was 1.2 g cm^{-3}, with a permanent wilting point of 12%. The temperature of soil and soil relative humidity (SRH) data were obtained from hygrothermograph (Logger L99-TWS-1, Hangzhou Loggertech Co., Ltd., Zhejiang, China) which was placed at a soil depth of 0.15 m (seed potato layer). In the whole growth stage, data were recorded at an interval of 1 h all the day and the daily mean data were calculated as the average of all the intraday readings.

2.4. Plant sampling

The main growth stages of potato including emergence, budding and yield were recorded when 75% of plants were showing the characteristics in their appearance in each block. The final height of plant was measured by the randomly selection of plants from each block. The dry matters of above-ground (including stems and leaves) and underground (including roots and tubers) parts of the plant were obtained after the fresh sample was cut into subsamples and kept in a brown paper bag for drying in an oven at 65 °C for more than 60 h (Wang et al., 2005). Yield, tuber number and tuber grade data were collected manually. After harvesting, in each block, the total tubers were weighed for yields and were divided into three grades based on fresh weight: > 150 g, 75–150 g and < 75 g. ≥75 g of tuber was evaluated as a commercial tuber (about 1.4 Yuan/kg RMB), and < 75 g of tuber was sold at a price of about 0.8 Yuan/kg (RMB) in 2015 and 2016. Tuber yield data were calculated and reported based on area (kg ha^{-1}) in all the treatments. Analyses on the economic benefits of potato under different cultivation patterns were based on the input, yield and price.

2.5. Statistical analyses

The significance of variation was analyzed using the software IBM SPSS Statistics 19.0. All the data were analyzed for using one-way analysis of variance (ANOVA). The analysis on the relationship was evaluated by grey relational analysis software (MATLAB 10a) in both years, and data were standardized before analysis.

3. Results

3.1. Weather conditions

In 2015, the daily mean air temperature was in the range of 13.0–24.6 °C, an average of 18.8 °C during the growth seasons. The daily maximum air temperature was from 9.3 °C (10 April) to 31.9 °C (28 May) and the minimum was in the range of −0.5 °C (13 April) to 19.6 °C (24 June). A maximum air temperature of > 30 °C was for 13 days, whereas for 4 days the temperature was less than 5 °C during the growth season. The daily air temperature was in the range of −0.5–30.9 °C during emergence (Fig. 2). In 2016, the mean day temperature was in the range of 13.5–24.6 °C, with an average temperature of 19.1 °C. A daily maximum air temperature was in the range of 8.3 °C (12 May)–30.6 °C (29 March) and the minimum temperature from −0.8 °C (20 April) to 19.3 °C (27 June, 28 June and 19 July). A maximum air temperature > 30 °C was existing for 4 days, whereas a temperature of less than 5 °C was existing for 4 days during the growth season. The daily air temperature was from −0.8 to 30.6 °C during emergence (Fig. 2).

The annual rainfall was 872.0 mm in 2015 which was more than the