

## **Allelopathic effects of aqueous extracts of potato (*Solanum tuberosum* L.) varieties on *Avena fatua* L. and *Brassica campestris* L. weeds in Qinghai-Tibet plateau**

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### **ABSTRACT**

We evaluated the allelopathic potential of Potato varieties to control weeds. The allelopathic effects of extracts from the leaves, stems and tuber tissues of 4-potato varieties (Qingshu 2, Qingshu 9, Xiazhai 65 and 175) collected at early, flowering and tuberisation stages were evaluated on the germination and seedlings growth of wild oats (*Avena fatua* L.) and rape (*Brassica campestris* L) weeds. The leaves, stems and tuber tissues of potato varieties, X65 and Q9 were significantly inhibitory to *Brassica campestris* L weed. The potato variety Q9 was more inhibitory than variety X65.

**Keywords:** Allelopathic effects, aqueous extracts, *Avena fatua*, *Brassica campestris*, flowering, leaves, rape, *Solanum tuberosum*, stems, tubers, tuberisation, varieties, weeds, wild oat

### **INTRODUCTION**

Potato (*Solanum tuberosum* L.) is main crop in Qinghai Province, China, but the weeds are great problem and only few herbicides are available for weed control in potato crop (5). Plants chemically affects the performance of neighbouring plants through allelopathy (2,11,12,20,21). Therefore, the study of chemical interactions among the plants may help to develop new environmentally friendly herbicides, or new management strategies to control weeds. Many plants exert inhibitory allelopathic effects on the growth and development of other susceptible plant species (1), such effects of allelochemicals (produced and released from the plants) may be exploited for weed control. Many plants produce allelochemicals for self defence against pests and to overcome biotic and abiotic stresses etc (8,16,17,22). The allelopathic effects of potato on other weed species have not been reported. This study aimed to identify the allelopathic effects of potato (*Solanum tuberosum* L.) varieties on major weed species in Qinghai-Tibet plateau. We studied the allelopathic effects of aqueous extracts from tissues of roots, shoots (leaves, stems) and tubers of 4 potato varieties were studied on germination and seedlings growth of *Avena fatua* L. and *Brassica campestris* L. weeds. This study could help in the development of new biological and environmentally friendly herbicides to control the wild oat and rape weeds in potato.

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## MATERIALS AND METHODS

These studies were done at the Qinghai Academy of Agriculture and Forestry Science, Xining, China (36°43'N; 101°45'E, at 2230 m above sea level). The 4 potato (*Solanum tuberosum* L.) varieties [Qingshu 2 (Q2), Qingshu 9 (Q9), Xiazhai 65 (X65) and 175] were sown in April and harvested in September 2015 at the Research Station, Tibet Plateau, Qinghai Province, China. The seeds (80-100 % germination) of wild oat (*Avena fatua* L.) and rape (*Brassica campestris* L.) were purchased from the local market.

### BIOASSAYS

The experimental treatments consisted of 4 factors: (i). Potato varieties: 4 [Qingshu 2 (Q2), Qingshu 9 (Q9), Xiazhai 65 (X65) and 175(V175)], (ii). 3 Aqueous extracts: 3 (roots, leaves and tubers), (iii). Aqueous extract concentrations: 3 (0,50,100 mg/ml) and (iv). Test weed species: 2 [wild oat (*Avena fatua*), rape (*Brassica campestris*)]. The treatments were replicated thrice in in complete randomized Design. Root50 : 50 mg/ml of aqueous extract of roots, Root100 :100 mg/ml of aqueous extract of roots, Leave50 : 50 mg/ml of aqueous extract of leaves, Leave100 : 100 mg/ml of aqueous extract of leaves, Tuber 50: 50 mg/ml aqueous extract of tubers, Tuber100 : 100 mg/ml of aqueous extract of tubers.

**Sample collection:** Roots, shoots (leaves, stems) and tubers tissues were collected from each potato variety at (i) early growth stage (3- leaf, 1 month after planting), (ii) flowering (2- months after the early vegetative stage) and (iii) early tuberisation (2- months after flowering) stages, respectively. At each growth stage, 45 plants were harvested by “W” method, and then partitioned into roots, shoots and tubers. All samples were dried in shade at room temperature (20 °C) for 7 days.

**Preparation of aqueous extracts of potato tissues:** The potato plant tissue samples were cut into small pieces (3 cm length). Then, 15 g tissue sample was soaked separately in 150 ml and 300 ml distilled water for 48 h at room temperature to obtain the aqueous extracts of 100 mg/ml and 50 mg/ml concentrations, respectively. The slurry was filtered twice with filter paper and the obtained aqueous extract was filtered again through 0.22 µm Millipore filter and stored at 4 °C (9).

The effects of these aqueous extracts were assessed on the germination and seedling growth of *A. fatua* and *B. campestris* weeds in petri-plate bioassay. All Petri-dishes (9 cm dia) were sterilized at 121 °C for 20 min in an autoclave. The test seeds were sterilized by soaking in 5 % NaClO solution for 10 mins and then washed thrice with sterile water. Sixteen uniform sterilized seeds of *A. fatua* and 20 seeds of *B. campestris* were sown equidistant in each Petri dish lined with filter paper. Distilled water was used as control. Six ml extract or distilled water was added per petri dish asper treatments. These petri-dishes were kept in an incubator (24°C, with light intensity  $356 \pm 0.16 \times 10^3$  lux for 8 h). The germination and seedling growth (root length, shoot length and dry weight) of recipient plants were determined 7 days after incubation (1).

**Statistical Analysis:** The root lengths, shoot lengths, dry weight and inhibition rate were subjected to one-way ANOVA analysis of variance followed by Duncan’s multiple-range test to determine significant differences among mean values at the probability level of 0.05 (4). All bioassays were done thrice under identical conditions. Data are means  $\pm$  SE.

## RESULTS AND DISCUSSION

### (I). EARLY GROWTH STAGE

#### (i). *A. fatua*

**Germination:** The aqueous extracts of all 4 potato varieties significantly decreased the seeds germination of *A. fatua*. The leave50 of X65 variety were most inhibitory (> 30 % inhibition) followed by Tuber 50 of X65 variety. Among all varieties, X65 and 175 varieties were more inhibitory. The phytotoxicity of potato varieties followed the Order: X65 > V175 > Q2 > Q9 (Fig. 1).

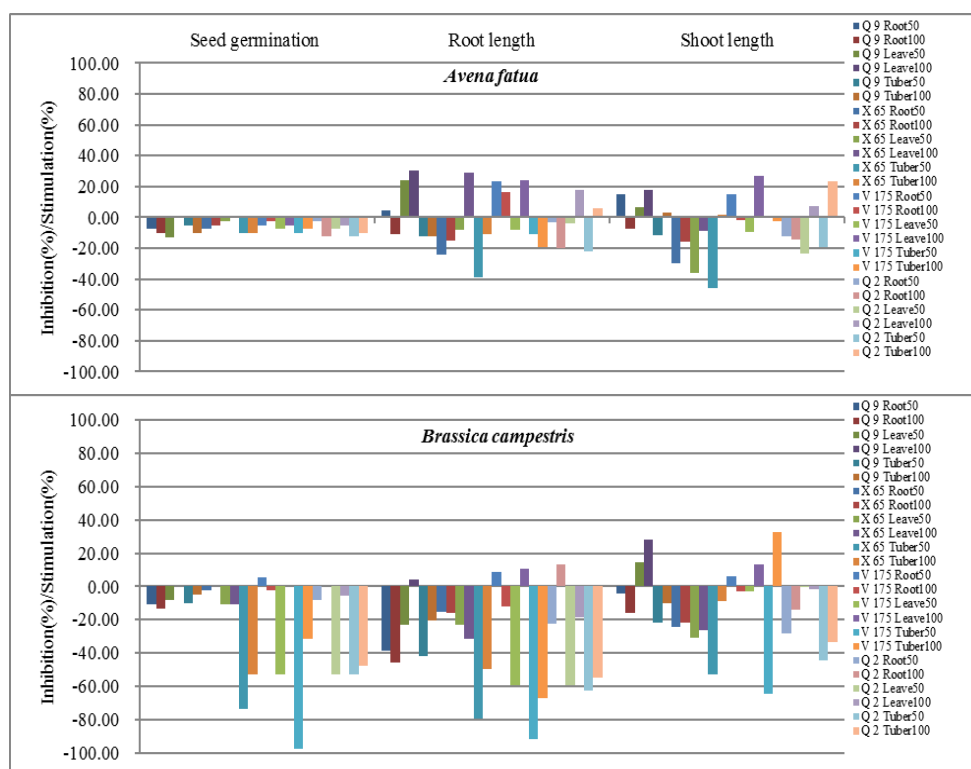


Figure 1. Inhibitory and stimulatory effects of aqueous extract concentrations of different organs of 4-potato varieties at Early (3-Leaf) stage on seed germination and seedling growth of *A. fatua* and *B. Campestris* at 7-days after sowing.

Root50 : 50 mg/ml of aqueous extract of roots, Root100 : 100 mg/ml of aqueous extract of roots, Leave50 : 50 mg/ml of aqueous extract of leaves, Leave100 : 100 mg/ml of aqueous extract of leaves, Tuber50 : 50 mg/ml of aqueous extract of tubers, Tuber100 : 100 mg/ml of aqueous extract of tubers.

**Root length:** Only X65 variety Leave50 aqueous extracts moderately inhibited (-50.2%) the root length (Fig. 1). While its Leave100 aqueous extracts moderately stimulated (+46.7 %) the root length. The Q9 potato variety Leave100 and Q2 variety

Leave100 aqueous extracts significantly stimulated (+61.7 %, +68.8%, respectively) the root length. All treatments of potato Q2 variety aqueous extracts stimulated the root length (Fig. 1).

**Shoot length:** Only X65 variety Leave50 aqueous extracts significantly inhibited (-62.8%) the shoot length (Fig. 1). Its Tuber100 and 175 variety Leave50 aqueous extracts moderately inhibited (-42.1%, -49.2%, respectively) the shoot length (Table 3 and Fig. 1). However, Q9 variety Leave100 and Tuber50 aqueous extracts significantly stimulated (+78.3%, +79.6 %, respectively) the shoot length. While, The X65 variety Root50, 175 variety Leave100 and Q2 variety Leave50 aqueous extracts were moderately stimulatory (+53.0 %, +51.1 %, +54.6 %, respectively) to shoot length of *A. fatua* (Fig. 1).

#### (ii). *B. Campestris*

**Germination:** As compared to *A. fatua*, the germination of *B. campestris* was more affected by aqueous extracts of four potato varieties. The Tuber50 aqueous extract of X65 variety completely inhibited the seeds germination of *B. campestris*. The Leave50 aqueous extract of potato varieties Q9, X65 and V175 caused > 80% reduction in seeds germination. However, Leave100 aqueous extract of potato varieties X65 and Q2 did not cause any stimulation/ inhibition. Among all 4- potato varieties Q2 variety was least phytotoxic to the seeds germination *B. campestris* (Fig. 1).

**Root length:** Most potato varieties aqueous extracts inhibited the root length (-40.0% to-100.0%) of *B. campestris* seedlings (Fig. 1). Twelve treatments of aqueous extracts (Q9 variety Root50, Leave50, Tuber50 and Tuber100, X65 variety Root50, Leave50, Tuber50 and Tuber100, 175 variety Leave50, and Leave100 and Q2 variety Leave50 and Tuber100) significantly inhibited the root length. The X65 potato variety Tuber50 aqueous extract completely inhibited (100% inhibition) the root growth (Fig. 1).

**Shoot length:** The X65 potato variety Tuber50 aqueous extract also completely inhibited (100% inhibition) in the shoot growth of *B. campestris* seedlings (Fig. 1). While its Leave50 aqueous extract significantly inhibited (-72.5 %) the shoot growth. However, other treatments of aqueous extracts did not inhibit the shoot length. On the contrary, Q9 variety Tuber50, X65 variety Leave100, and Q2 variety Leave100 aqueous extract significantly stimulated (+58.1 %, +77.5 %, +70.5 %, respectively) the shoot length (Fig. 1).

All 4 potato varieties (Q2, Q9, X65, V175) inhibited the seeds germination of both test weeds (*A. fatua*, *B. Campestris*) at 50 and 100 mg/ml Concentrations. The inhibitory effects of aqueous extract concentrations followed the Order: Leave > Tuber > Root (except for X65 variety on *B. Campestris*). The X65 potato variety significantly inhibited the root length and shoot length of both test weeds. The Leave50 aqueous extract of X65 variety was the most inhibitory (-72.5%) to shoot length.

## (II). FLOWERING STAGE

#### (i). *A. fatua*

**Germination:** The aqueous extracts of plant parts of all four varieties (Q2, Q9, X65, V175) inhibited the seeds germination of *A. fatua* weed (Fig. 2). However, the

inhibition was up to 20 %. The potato variety Q9 leave50 aqueous extract was more inhibitory (-13.3 %) than Root100 (-10.0 %) and Tuber50 (-10.0 %) of potato variety Q2. The effects of Leave100 aqueous extracts of potato varieties Q9 and X65 slightly influenced the seeds germination of *A. fatua* weed (Fig. 2).

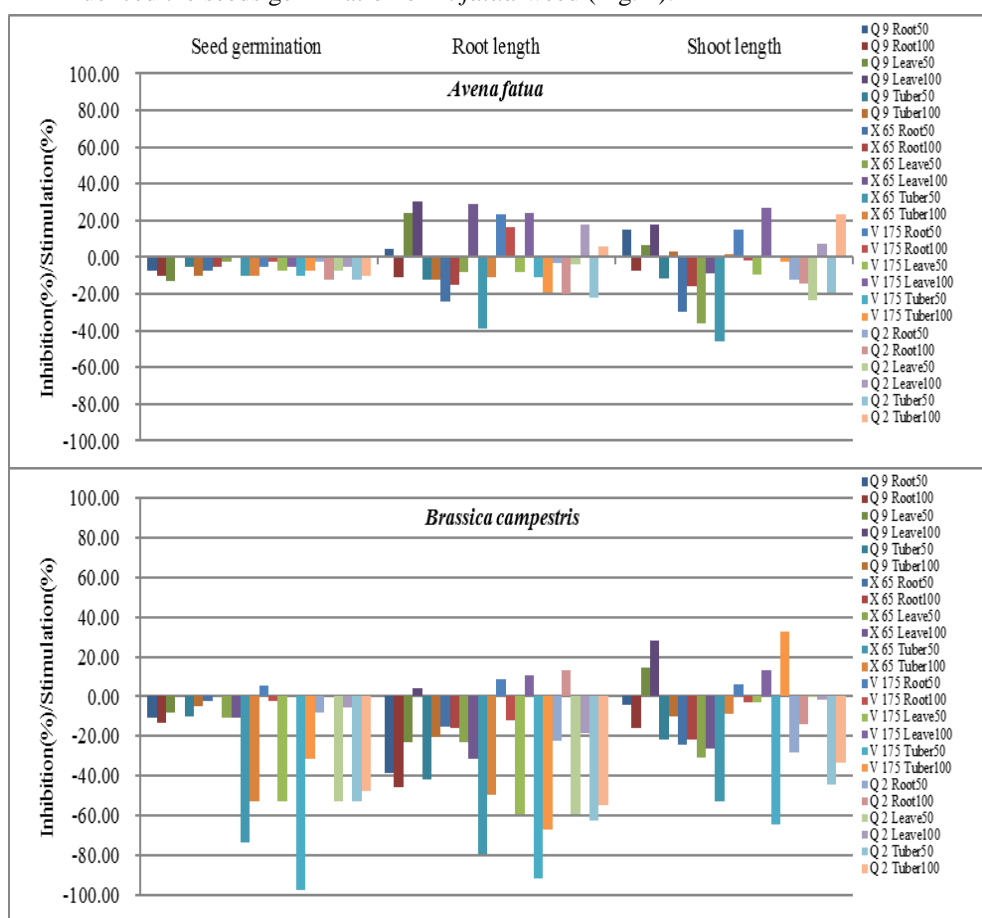


Figure 2. Inhibitory and stimulatory effects of aqueous extract concentrations of different organs of 4-potato varieties at flowering stage on seed germination and seedling growth of *A. fatua* and *B. campestris* at 7-days after sowing.

Root50 : 50 mg/ml of aqueous extract of roots, Root100 : 100 mg/ml of aqueous extract of roots, Leave50 : 50 mg/ml of aqueous extract of leaves, Leave100 : 100 mg/ml of aqueous extract of leaves, Tuber50 : 50 mg/ml of aqueous extract of tubers, Tuber100 : 100 mg/ml of aqueous extract of tubers.

**Root length:** None of the aqueous extracts from organs of various potato varieties inhibited the root length (Fig. 2) of *A. fatua* seedlings. On the contrary, the potato Q9 variety Leave50 and Leave100 aqueous extracts were stimulatory (+24.3 %, +30.3 %, respectively) to root elongation. The potato variety X65 Leave100 (+29.1 %

stimulation), V175 variety Root50, Root100, and Leave100 aqueous extracts were stimulatory (+23.7 %, +16.2 %, +23.9 %, respectively) to root elongation. Whereas, the potato variety Q2 Leave100 aqueous extracts were less stimulatory (+17.9 %). Root elongation was more sensitive to aqueous extracts than shoot elongation (Fig. 2).

**Shoot length:** None of the treatments inhibited the shoot length (Fig. 2). Q9 variety Leave100, V175 Leave100 and Q2 variety Tuber100 aqueous extracts weakly stimulated the shoot length (+17.6 %, +26.8 %, +23.5 %).

#### (ii). *B. Campestris*

**Germination** The effects of aqueous extracts of potato varieties had variable effects on the seeds germination of *B. campestris* (Fig. 2) The Tuber50 aqueous extracts of potato variety 175 caused the maximum inhibition (-97.40 %) followed by Tuber50 aqueous extracts of X65 variety (-73.70 % inhibition). However, the aqueous extracts of Root50 of potato variety 175 stimulated (+5.3%) the seeds germination of *B. campestris*. Whereas, the aqueous extracts of Leave100 of Q9 variety, Root100 of X65 variety and Leaves100 of 175 variety did not influence the seeds germination. In comparison to *A. fatua*, the seeds germination of *B. campestris* was more inhibited by the aqueous extracts of Leave50, Leave100, Tuber50, and Tuber100 aqueous extracts (-10.5 %, -10.5 %, -73.7 %, -52.6 %, -52.6 %, -5.3 %, -52.6 %, and -47.7 %, respectively) of potato varieties X65 and Q2. The Leave50, Tuber50, and Tuber100 (-52.6 %, -94.7 %, and -31.6 %, respectively) of potato variety 175.

**Root length:** Only four aqueous extracts (X65 variety Tuber50, 175 variety Tuber50 and Tuber100, and Q2 Tuber50) significantly inhibited the root elongation (-79.4 %, -91.8 %, -66.8 %, and -62.7%, respectively) (Fig. 2). The Tuber50 of potato 175 variety was most inhibitory (-91.8 %) to root length. On the contrary, Q9 potato variety aqueous extracts of Root100 was stimulatory (+13.2 %) to root elongation of *B. Campestris* (Fig. 2).

**Shoot length:** Only potato variety 175, Tuber50 aqueous extract had significant inhibitory effects (-64.2 %) on the shoot length of *B. campestris* (Fig. 2). Contrarily, the potato Q9 variety Leave50 and Leave100 aqueous extract were stimulatory (+14.7 %, +28.4 % respectively) to the shoot length of *B. campestris*.

At flowering stage, all 4 varieties did not inhibit the seeds germination of *A. fatua* weed. The Tuber 50 aqueous extract of 175 potato variety significantly inhibited the root length and shoot length of two test weeds. The Tuber 50 aqueous extract of varieties X65, 175 and Q2 was most inhibitory (-53.1 %, -64.2 %, and -44.1 %, respectively).

### (III). TUBERISATION STAGE

#### (i). *A. Fatua*

**Germination:** The aqueous extracts from the Tuberisation stage of potato varieties had both inhibitory and stimulatory effects on the seeds germination and seedlings growth of *A. fatua*. Among all the treatments, Q9 potato variety Leave50 aqueous extracts were most inhibitory (> 80 % reduction) to seeds germination but Tuber 50 aqueous extracts were slightly stimulatory to germination. The potato X65 variety, Leave50 aqueous extract were most phytotoxic (-57.9 %) followed by Leave100 extract (-13.2 %), while Tuber50 and

Tuber100 aqueous extracts slightly stimulated (+5.3 %, +5.3 %) the seeds germination. The 175 and Q2 varieties of potato were slightly inhibitory/ stimulatory to germination of *A. fatua*. In all treatments, Tuber100 aqueous extract of Q9 variety, Root50, Root100 and Tuber100 aqueous extract of variety 175 and Root50 and Leave100 aqueous extract of Q2 variety slightly affected the seeds germination of *A. fatua* (Fig. 3).

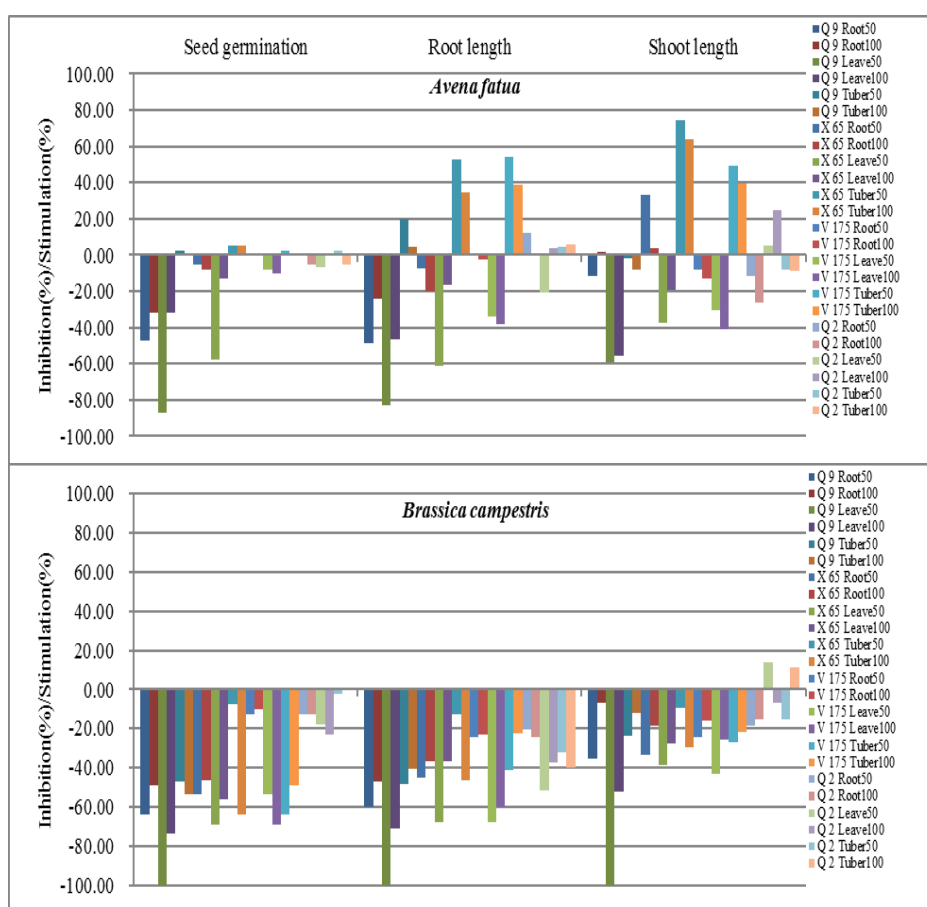


Figure 3. Inhibitory and stimulatory effects of aqueous extract concentrations of different organs of 4-potato varieties at Tuberisation stage on seed germination and seedling growth of *A. fatua* and *B. campestris* at 7-days after sowing.

Root50 : 50 mg/ml of aqueous extract of roots, Root100 : 100 mg/ml of aqueous extract of roots, Leave50 : 50 mg/ml of aqueous extract of leaves, Leave100 : 100 mg/ml of aqueous extract of leaves, Tuber50 : 50 mg/ml of aqueous extract of tubers, Tuber100 : 100 mg/ml of aqueous extract of tubers.

**Root length:** Only potato Q9 variety Leave50 aqueous extract and X65 variety Leave50 aqueous extracts significantly inhibited (-83.1 %, -61.1 %) the root length of *A. fatua* seedlings (Fig. 3). Whereas, only potato variety X65 Tuber 50 and 175 variety

Tuber 50 aqueous extracts moderately stimulated (+52.5 %, +53.9 %, respectively) the root length.

**Shoot length:** The potato X65 variety Tuber50 and Tuber100 aqueous extract significantly stimulated (+74.5 %, +64.2 %, respectively) the shoot length (Fig. 3). Contrarily, Q9 variety Leave50 and Leave100 aqueous extract were the moderately inhibitory (-59.2 %, -55.8 %, respectively) to shoot elongation.

**(ii). *B. Campestris***

**Germination:** The tuberisation stage of all four potato varieties was most inhibitory to the seeds germination of *B. campestris*. Among all treatments, Q2 variety was least inhibitory, with Tuber50 aqueous extract had negligible impact and Tuber100 did not affect the seeds germination of *B. campestris*. The Leave50 aqueous extract of potato variety Q9 was most inhibitory i.e. caused completely inhibition (-100.0 %) (Fig. 3).

**Root length:** Four treatments (Leave50 and Leave100 aqueous extracts of Q9 potato variety, Leave50 of X65, and Leave50 of 175 variety) significantly inhibited (-100.0 %, -71.0 %, -67.7 % and -67.7 %) the root length *B. campestris* seedlings (Fig. 3). Especially, Leaves50 aqueous extracts of Q9 variety, completely inhibited (100% inhibition) the root elongation.

**Shoot length:** Only Q9 variety Leave50 aqueous extract completely inhibited (100% inhibition) the shoot length of *B. campestris* seedlings. At tuberisation stage, Q9 variety significantly inhibited the seeds germination of both test weeds (*A. fatua*, *B. campestris*). The potato Q9 variety Leave50 aqueous extract significantly inhibited the root length and shoot length of both test weeds. The Leave50 of Q9 variety was most inhibitory and caused -100 % inhibition.

At 3-stages (Early growth, Flowering, Tuberisation), the inhibitory allelopathic potentials of potato varieties were different. In early growth stage, the X65 potato variety was most allelopathic. At the flowering stage, 175 potato variety was most allelopathic, while, at the tuberisation stage the Q9 potato variety was most allelopathic.

Also, the allelopathic plant parts of potato were different at various growth stages. Leave part were most allelopathic part in both early growth and tuberization stages. The tubers were most allelopathic part of potato at the tuberisation stage.

In this study, X65 and Q9 potato varieties Leaves50 proved allelopathic and significantly inhibited the test weeds root length and shoot length at early growth and tuberisation stages. The potato variety Q9 was more allelopathic than X65 at tuberisation stage. Both potato varieties Q9 and X65 (bred in Qinghai Province), are very robust, high yielding, with well be developed root system, hence, very suppressive to weeds (9,19).

The rice and wheat varieties, with superior characteristics (luxuriant growth, high tillering and well developed root system) are allelopathic varieties (10). Most treatments of aqueous extracts significantly inhibited the seedling growth in both weeds species (*A. fatua*, *B. campestris*) (Figs. 1-3). Rice, wheat, beans and other plants, also exerts inhibitory effects on the weeds in the seedling stage (6,13,15,18), indicating that the seedling stage is the most sensitive to allelopathic effects. There were also many differences in allelopathic effects between the aqueous extracts concentrations. For example the effects of Leaves and

Tubers concentrations of 50 and 100 of 4 potato varieties differed at the early growth and flowering stages. Some plants had allelopathic effects, “stimulatory at low concentrations, while inhibitory at high concentrations” due to different kinds of secondary metabolites. Maybe there are similar compounds in leaves or tubers of 4 potato varieties, which show the negligible effects on seeds germination and seedlings growth of test weed species.

Most of the treatments of the aqueous extracts had significant inhibitory effects on *B. campestris*. The root length and shoot length are important indexes to evaluate the allelopathic effects (3,7,21). These results also indicated that the potato, leaf, stem and tubers have allelopathic potential to control the weeds after more detailed investigations are done. Our results are in conformity with others findings, where, the aqueous extracts of rice leaf were inhibitory to some weeds (4,14,19). Allelochemicals are mainly secondary metabolites and these are produced in leaves through photosynthesis, thus leaf is source of many allelochemicals (6). More interestingly, potato tubers also proved allelopathic organ. Potato tuber is subterraneous stem and performs the function of stem as done by the above ground stem in other plants. The potato tuber also exerts allelopathic effects similar to stem in rice plant (6,14,19). Thus potato tubers also exerted the allelopathic effects on weeds, in the way similar to the effects of root and stem of other plants.

## CONCLUSIONS

The different tissues of four potato varieties (Q2, Q9, X65, V175) were allelopathic to *A. fatua* and *B. campestris* weeds. At early growth stage, all 4 potato varieties inhibited the seeds germination of both test weeds at 50 and 100 mg/ml concentrations. The X65 potato variety was most inhibitory to root length and shoot length of both weeds. The Leave50 aqueous extract of X65 variety was most inhibitory to shoot length. At flowering stage, all 4 varieties did not inhibit the seeds germination of *A. fatua* weed. The Tuber 50 aqueous extract of 175 potato variety significantly inhibited the root length and shoot length of both weeds. The Tuber 50 aqueous extract of varieties X65, 175, and Q2 was most inhibitory. At tuberisation stage, Q9 variety significantly inhibited the seeds germination of both test weeds. The potato Q9 variety Leave50 aqueous extract significantly inhibited the root length and shoot length of both test weeds.

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