

Full Length Research Paper

Effect of six environmental variables on five *Bupleurum* species distribution in Guandi, Wutai, Xiaowutai and Dongling mountains

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Received 2 April, 2011; Accepted 9 May, 2011

Effects of environmental factors on the spatial distribution of five *Bupleurum* genera were investigated. Eighty seven samples in total in four mountains were collected; 158, 116, 130 and 128 plant species were recorded in Guandi, Wutai, Xiao Wutai and Dongling mountains, respectively. This study has been focused on five particular species (*Bupleurum bicaule* Helm, *Bupleurum scorzoniferifolium* Willdenow, *Bupleurum sibiricum* Vest, *Bupleurum smithii* H.Wolff and *Bupleurum chinense* DC) not only because of their medicinal properties, but also because of the threat they are subject to. Relations between environmental variables and their influence on these species distribution were analyzed using CANOCO software correlation statistical analysis. The distribution of these five species was found to be differently influenced by environmental variables. However altitude and vegetation type appeared to be the variables which influenced the most *Bupleurum* distribution in the four surveyed mountains. Preservation of these areas from human disturbance or nevertheless activity controlled by the establishment and strengthening of protected areas could be a solution for a sustainable management.

Key words: *Bupleurum bicaule*, *Bupleurum scorzoniferifolium*, *Bupleurum sibiricum*, *Bupleurum smithii*, *Bupleurum chinense*, environmental variable, canonical correspondence analysis (CCA) multiple species response curves.

INTRODUCTION

Bupleurum genus of the Apiaceae family has from 250 to 455 genera and 3,300 to 3,700 species widely distributed in the temperate zone of both hemispheres, mainly in Eurasia and especially in Asia (Sofi et al., 2009; Menglan et al., 2005). *Bupleurum* genus is one of the fifteen commonly used herbs in the Traditional Chinese Medicine (TCM) (Subhuti, 1996). Day to day TCM is gradually recognized and applied in the world, making the increase demands for the TCM in the international market (China Patent Medicine Industry Report, 2010). Market development included differentiated demand for herbal

product formulation, specially an increasing preference for products made of combinations of herbs over those based on single herbs (Blumenthal et al., 2006).

In 2005, the output value of TCM amounted to about €11 billion (1/4 of the overall output value in China's medical industry) and will rise to €18.8 billion in 2015. Customs figures show China exports 240,000 tons of medicines annually, of which 200,000 tons are raw herbs. The exported raw herbs accounted for 20% of the country's annual harvest. Many provinces such as Hebei, Guizhou, Yunnan, Sichuan, Shaanxi and Shanxi have

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designated traditional medicine as a pillar industry (Helmut Kaiser Consultancy Studies, 2009).

Nowadays, because of their potential bio-active components as medicinal plant, exploitation of *Bupleurum* species for herbal purposes has become a new source of income for some Chinese farmers, but also source of species threat among which excessive picking and digging, deforestation, excessive herding and reclamation of grassland, tourism, urbanization, etc (www.biodiv.gov.cn). The herb material supply is cultivated or wild; this latter case is an issue which could lead from the shortage to the threat of defunctness of this genus which goes with seasonal variation. Indeed, in many surveyed places in Shanxi, Hebei provinces of China, where *Bupleurum* spp. were occurring few years ago, with peasants' farms extension and grazing, some of these species are no more present nowadays. This study besides promoting conservation and diversification of these resources, also gives a sounding alarm on the management of these areas.

The present survey investigated the correlations between the distribution of five *Bupleurum* spp. and six environmental variables over four geographical environments in Guandi, Wutai, Xiao Wutai and Dongling mountains in China. The conclusion of this study gave an idea how these species responded to these environmental variables; and also could lead to some insights on how to plan environmental assessment and impact analysis which could contribute to the conservancy process of these important species.

METHODOLOGY

Study area

Guandi mountain is located in the West of Shanxi province of China, with the highest peak of 2831 m above the sea level (m a.s.l.). Its geographical position is N37°20' to 38°20' and E110°18' to 111°18', and is part of Luliang mountain range (Gao and Zhang, 2006). The climate is a warm temperate semi-humid continental monsoon; the average annual temperature varies from 3 to 4°C. The annual frost-free period is about 100 days and the mean annual precipitation is about 838.8 mm (Zhang and Yang, 2008). Several soil types are encountered there, such as mountain cinnamon soil, brown forest soil and mountain meadow soil (Zhang and Meng, 2007); with the temperate coniferous forest (1650 to 1800 m), the broadleaf forest (1650 to 2150 m), the cold temperate coniferous forest (1800 to 2600 m) and the sub-alpine shrub meadow (2550 to 2831 m) (Yuan et al., 2004).

Wutai mountain located in the North side of Shanxi province of China between 38°30' to 39°15'N and 112°50' to 113°50'E, belongs to Taihang ranges and is one of the four Buddhist shrines of China (Ru and Feng, 2000). Wutai mountain area is a warm temperate semi-humid monsoon climate. The soil types from the foothills to the summit are: cinnamon soil, brown forest soil, and sub-alpine meadow soil. Wutai mountains has some typical characteristics of warm temperate deciduous broad-leave forest (Ru and Feng, 2000). Xiao Wutai mountain is located in Zhangjiakou, Hebei province of China. Its geographical coordinates are longitude 114°47' to 115°30' and latitude 39°50' to 40°07' with a top peak altitude of 2882 m a.s.l. Xiao Wutai mountain has a temperate continental

monsoon climate with an average temperature of 6.4°C and annual rainfall varying from 400 to 700 mm (Liu et al., 2004). Xiao Wutai mountain area soils are cinnamon, mountain brown and sub-alpine meadow soils. Vegetation are (1) sub-alpine meadow, (2) subalpine shrub zone, (3) coniferous forest, (4) broad-leaved forest zone, (5) broadleaf forest, (6) secondary shrub zone, and (7) fruit farm belt (Liu et al., 2004).

Dongling mountain (2303 m) is a mixed woodland, Beijing Forest Ecosystem Research Station of the Chinese Academy of Sciences, 117 km Western of Mentougou district of Beijing, its geographical position is 39°48'N to 40°02'N, 115°24' to 115°36'E and located at an average altitude of 1075 m a.s.l (Liu et al., 2010; Xu and Zhang, 2008; Guo et al., 2004). The area is characterized by a temperate semi-humid monsoon climate with an annual temperature of 6.3°C. The annual mean precipitation is about 612 mm. The dominant soil type is cinnamon soil, with organic matter content of 8.8%, pH value of 6.34 and total nitrogen content of 0.45%. The main vegetation type is deciduous broadleaves forest of warm temperate zone (Liu et al., 2010).

Data collection

Data were collected from June to August, 2010. Along the altitudinal gradient between 1755 and 2714 m a.s.l, 1645 to 2502 m a.s.l, 1378 to 2194 m a.s.l and 1133 to 2303 m a.s.l, respectively for Guandi, Wutai, Xiao Wutai and Dongling mountains. Four types of sampling points were set up, and at least 5 quadrats around each sampling point were established randomly. Species data were recorded in each quadrat. The quadrats sizes were 10 m × 10 m for broadleaves, coniferous forest and shrubs; and 1 m × 1 m small quadrats were used to record herbs. The coverage of trees, shrubs and herbs were evaluated in each quadrat. Altitude, slope and slope aspect for each quadrat were also recorded. Altitude for each quadrat was measured by using an altimeter, the slope and slope aspect measured by using a compass meter (Zhang 2004; Zhang et al., 2006). Soil samples at a depth of 20 cm, in three random places were collected and mixed inside each quadrat for soil type and pH determination.

Data analysis methods

To appreciate the relations between *Bupleurum* spp. with environmental variables in each of the surveyed sites, Generalized Linear Model Multiples Species Response Curve have been used with a quadratic degree, Poisson distribution model, with a maximum value of binomial total value without transformation analysis of canonical correspondence analysis of CANOCO correlation statistical analysis program (Ter Braak and Smilauer, 2002). The pH of the soil has been measured in the supernatant suspension of a 1:5 soil:liquid (v/v) mixture according to the methods reference SA 06-ISO 10390 (1994) and Kissel and Vendrell (2004). The rope test has been used to figure out the type of collected soil (Dolezal, 2002).

RESULTS

Relation *Bupleurum* spp. and altitude

In Guandi mountain, *B. bicaule* occurred in the whole surveyed range area with a peak at around 2300 m a.s.l (Figure 1a). In Wutai mountain, *B. bicaule* showed a peak between 2000 and 2200 m a.s.l. *Bupleurum scorzonrifolium* occurred only between 1600 and 1700 m a.s.l with a peak approximately at 1650 m a.s.l (Figure

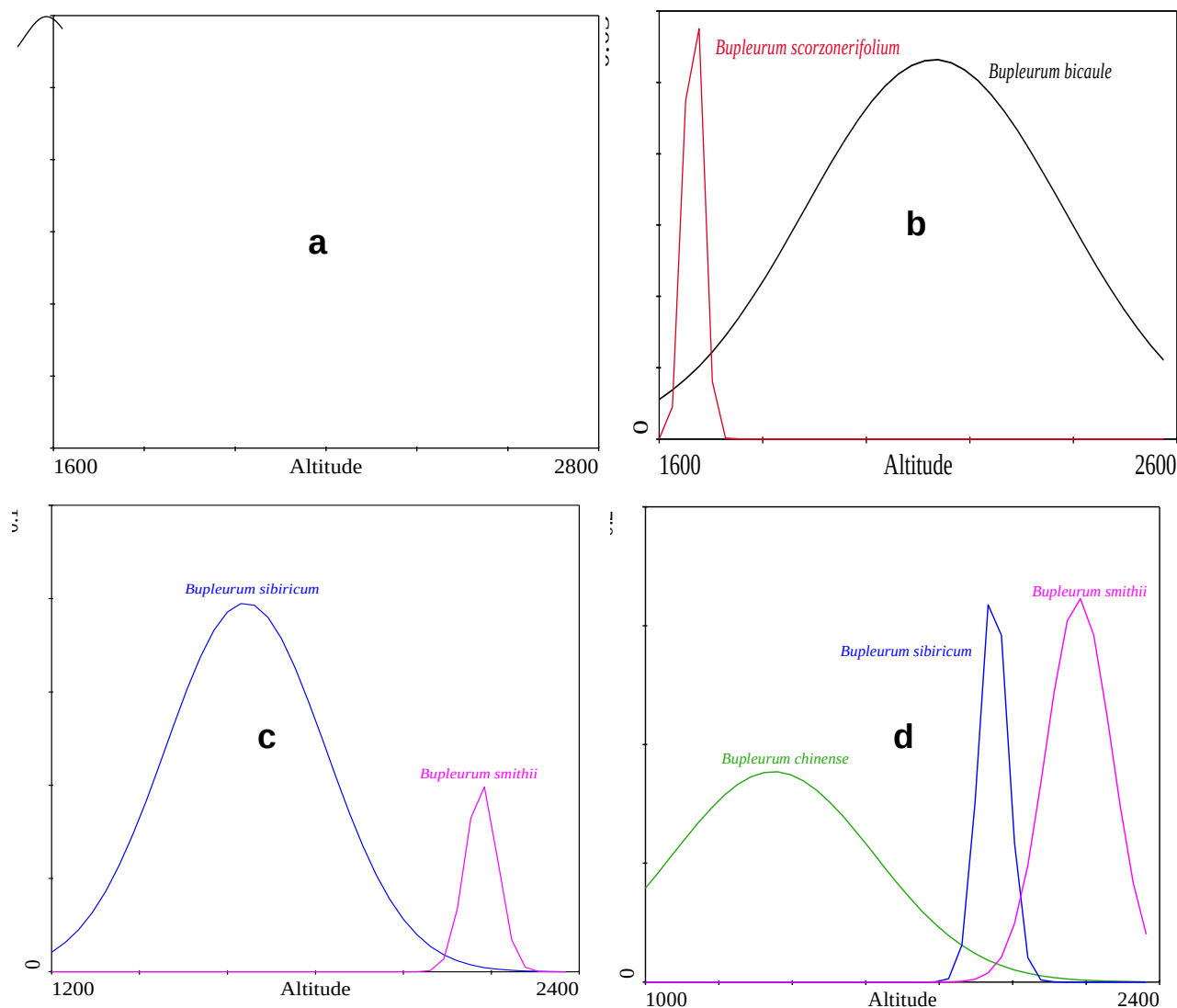


Figure 1. Response curves of *Bupleurum bicaule* (black) and *Bupleurum scorzonrifolium* (red) *Bupleurum sibiricum* (blue), *Bupleurum smithii* (purple) and *Bupleurum chinense* (green) on the variable altitude in Guandi (a), Wutai (b), Xiao Wutai (c) and Dongling (d) Mountains.

1b). In Xiao Wutai mountain, *Bupleurum sibiricum* response curve showed a peak around 1600 m a.s.l. *Bupleurum smithii* response curve showed a narrow occurrence space, between approximately 2100 and 2300 m a.s.l with a peak at 2200 m a.s.l. (Figure 1c). In Dongling mountain, *B. sibiricum* occurred between 1800 and 2100 m a.s.l with a peak at 1900 m a.s.l. *B. smithii* occurred in the interval 1900 to 2400 m a.s.l with a peak at 2200 m a.s.l. *Bupleurum chinense* showed a peak at 1400 to 1600 m a.s.l. (Figure 1d).

The analysis of variance (ANOVA) revealed, four of the five *Bupleurum* spp. are correlated to altitude except *Bupleurum bicaule*. Stratification in distribution of *Bupleurum* spp. could be linked to the presence of different microclimates characteristic of each of the species, but the presence of *B. bicaule* in the whole

range of study showed its independence to this factor (Table 1).

Relation *Bupleurum* spp. and slope aspect

In Guandi mountain, *B. bicaule* optimum response was between 20 and 40° with a peak at 30° (Figure 2a). In Wutai mountain, *B. bicaule* response increased the slope aspect without a peak (Figure 2b). *B. scorzonrifolium* curve shows an optimum between 0 and 20° and decreased progressively the slope aspect (Figure 2c). In Xiao Wutai mountain, *B. sibiricum* optimum response was between 30 and 50° with a peak at 40°. *B. smithii*. In occurred in nil and above 80° slope aspect (Figure 2d). Dongling mountain, *B. sibiricum* occurred above 80°

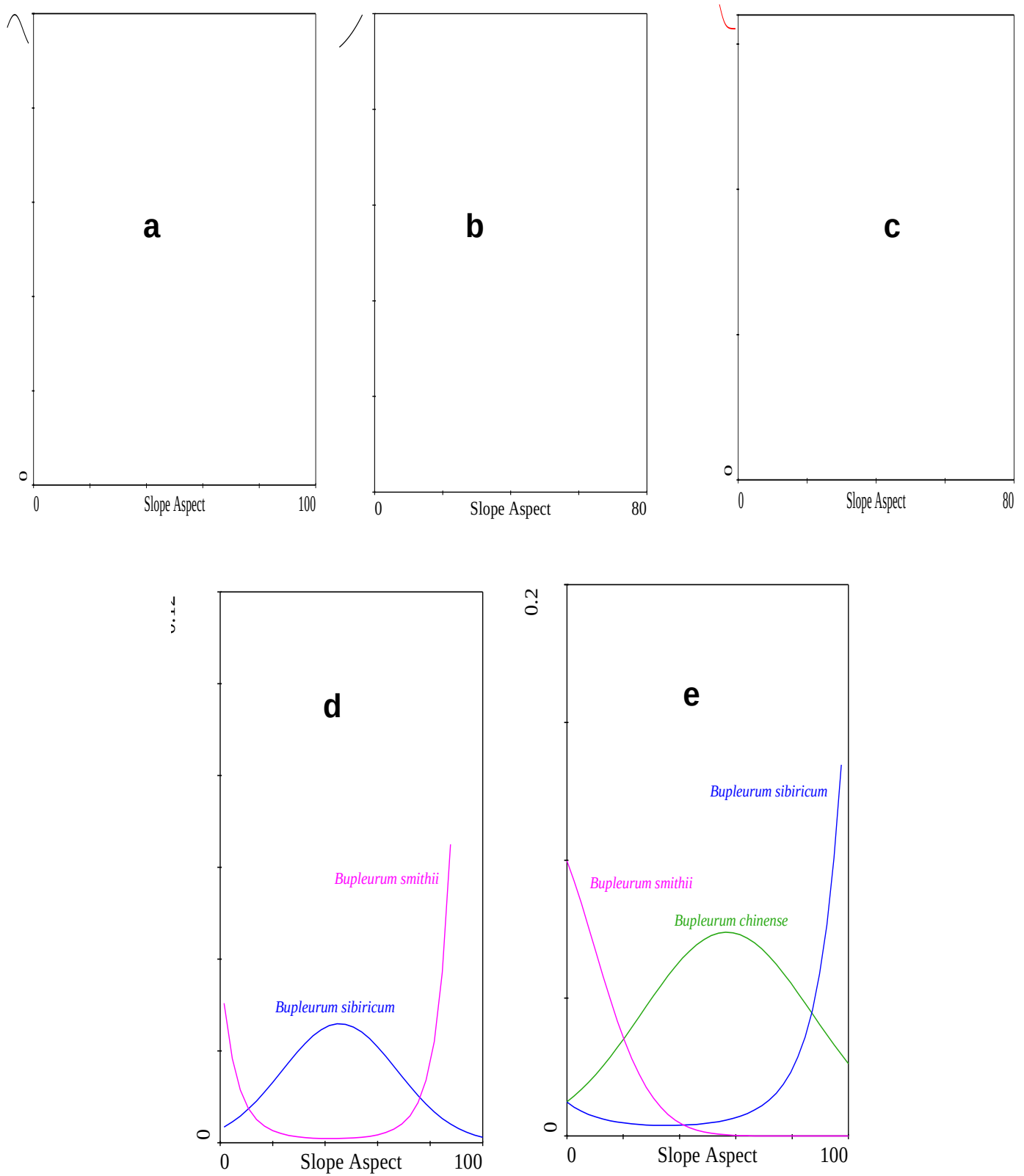


Figure 2. Response curves of *Bupleurum bicaule* (black) and *Bupleurum scorzonnerifolium* (red) *Bupleurum sibiricum* (blue), *Bupleurum smithii* (purple) and *Bupleurum chinense* (green) on the variable slope aspect in Guandi (a), Wutai (b, c), Xiao Wutai (d) and Dongling (e) Mountains.

slope aspect values. *B. smithii* occurred in slope aspect less than 20°. *B. chinense* occurred in the whole gradient with a peak between 40 and 70° slope aspect values (Figure 2e). Table 2 shows that the slope aspect was not a major factor in the distribution of *Bupleurum* spp. Observed difference could be linked to the variation of topography.

Relation *Bupleurum* spp. and pH

In Guandi mountain, *B. bicaule* response showed an optimum from pH 5.5 to 6.0 (Figure 3a). In Wutai mountain, *B. bicaule* response showed an optimum between pH 5.4 and 5.8. *B. scorzonrifolium* response peak was between pH 6.8 and 7 (Figure 3b). In Xiao Wutai mountain, *B. sibiricum* response curve increased with pH increase, this showed its preference for slightly to very slightly acid soil. *B. smithii* occurred in pH 5 to 5.4 with an optimum at 5.2 and showed its orientation for strongly acid soil (Figure 3c). In Dongling mountain, *B. chinense* occurred progressively with pH increase and showed its preference for very slightly acid, through neutral to very slightly alkaline soil (Figure 3b). *B. sibiricum* occurred between pH 4 and 5.5 with a peak at 4.75 and revealed its orientation for strongly acid soil (Figure 3b). *B. smithii* occurred between pH 5.5 and 6.25 with a peak at 5.75 and showed its preference for medium acid soil (Figure 3d).

The ANOVA revealed that *Bupleurum* spp. distribution is not correlated to pH. Soil composition could significantly make vary soil pH. A high or low concentration of OH ions could influence pH, leading to the observed differences (Table 3).

Relation *Bupleurum* spp. and slope

In Guandi mountain, *B. bicaule* slope occurrence range was between 0 and 40° with an optimum at approximately 20° (Figure 4a). In Wutai mountain, *B. bicaule* optimum response was at 30° while *B. scorzonrifolium* curve show no optimum, but a decrement until a lower point between 20 and 25° and an increment with the slope increased (Figure 4b). In Xiao Wutai mountain, *B. sibiricum* occurrence range was between 5 and 25° with an optimum at 15°. *B. smithii* lay along the entire horizontal gradient, but its response was high in slope values beyond 25° (Figure 4a). In Dongling mountain, *B. sibiricum* occurred in a narrow range from 25 to 35° with a peak at 30°. *B. smithii* occurred between 10 and 25° with a peak at 15°. *B. chinense* occurred between 0 and 10° and beyond 40° slope (Figure 4b).

The ANOVA showed that among the four surveyed sites, slope was a major factor in the *Bupleurum* spp. distribution in Dongling mountain. Indeed, different values of slope led to different exposure position to sunlight. Difference observed could be linked to the topography

Variations (Table 4).

Relation *Bupleurum* spp. and soil type

Two types of soil have been recorded in the surveyed areas. Type 1 was the loamy soil and type 2 was the sandy soil (1 and 2 along the graph horizontal axis, respectively).

In Guandi mountain, *B. bicaule* response was a straight declining line from left to right, showing that *B. bicaule* occurred preferably in loamy soil (Figure 5a). In Wutai mountain, *B. bicaule* response to soil type was similar to the one in Guandi mountain, while *B. scorzonrifolium* response increased along the horizontal axis from left to right and show its preference for soil type 2, that is, sandy soil (Figure 5b). In Xiao Wutai mountain, *B. sibiricum* response was an increasing arc of circle from left to right, and showed its preference for sandy soil. *B. smithii* response was a decreasing arc of circle from left to right and showed its orientation for loamy soil (Figure 5c). In Dongling mountain, *B. chinense* response showed occurrence in both types of soil but with a preference for sandy soil. *B. sibiricum* and *B. smithii* occurred only in loamy soil, that is, type 1 (Figure 5d). The ANOVA showed that *B. sibiricum* distribution correlated with the soil type. Observed differences for the other species could be linked particularly to the ability of their adaptation ability (Table 5).

Relation *Bupleurum* spp. and vegetation type

Four types of vegetation have been surveyed in Xiao Wutai and Dongling mountains: type 1 is coniferous forest; type 2 is broadleaves forest; type 3 is shrubs land; and type 4 is grass land (1, 2, 3 and 4 along the graph horizontal axis, respectively).

In Guandi mountain, four types of vegetation have been surveyed: type 1 was coniferous forest; type 2 was broadleaves forest; type 3 was shrubs land; and type 4 was grass land (1, 2, 3 and 4 along the graph horizontal axis, respectively). In Guandi mountain, *B. bicaule* occurred preferably in vegetation types 1 and 4, that is, coniferous forests and grass land (Figure 6a). In Wutai mountain, *B. bicaule* was able to grow in the 4 types of environment, but preferably in vegetation type 4, that is, grass land. *B. scorzonrifolium* occurred only in vegetation type 2 (Figure 6b). In Xiao Wutai mountain, *B. sibiricum* response was optimum in the transitional zone between broadleaves forest and shrubs land, while *B. smithii* occurred preferably in grass land (Figure 6c). In Dongling mountain, *B. chinense* was able to occur in the whole range of the surveyed vegetation types, but the curve showed its orientation for broadleaves forest (Figure 6d). *B. sibiricum* and *B. smithii* occurred only and preferably in grass land (Figure 6d).

The ANOVA showed all the five species are subject to

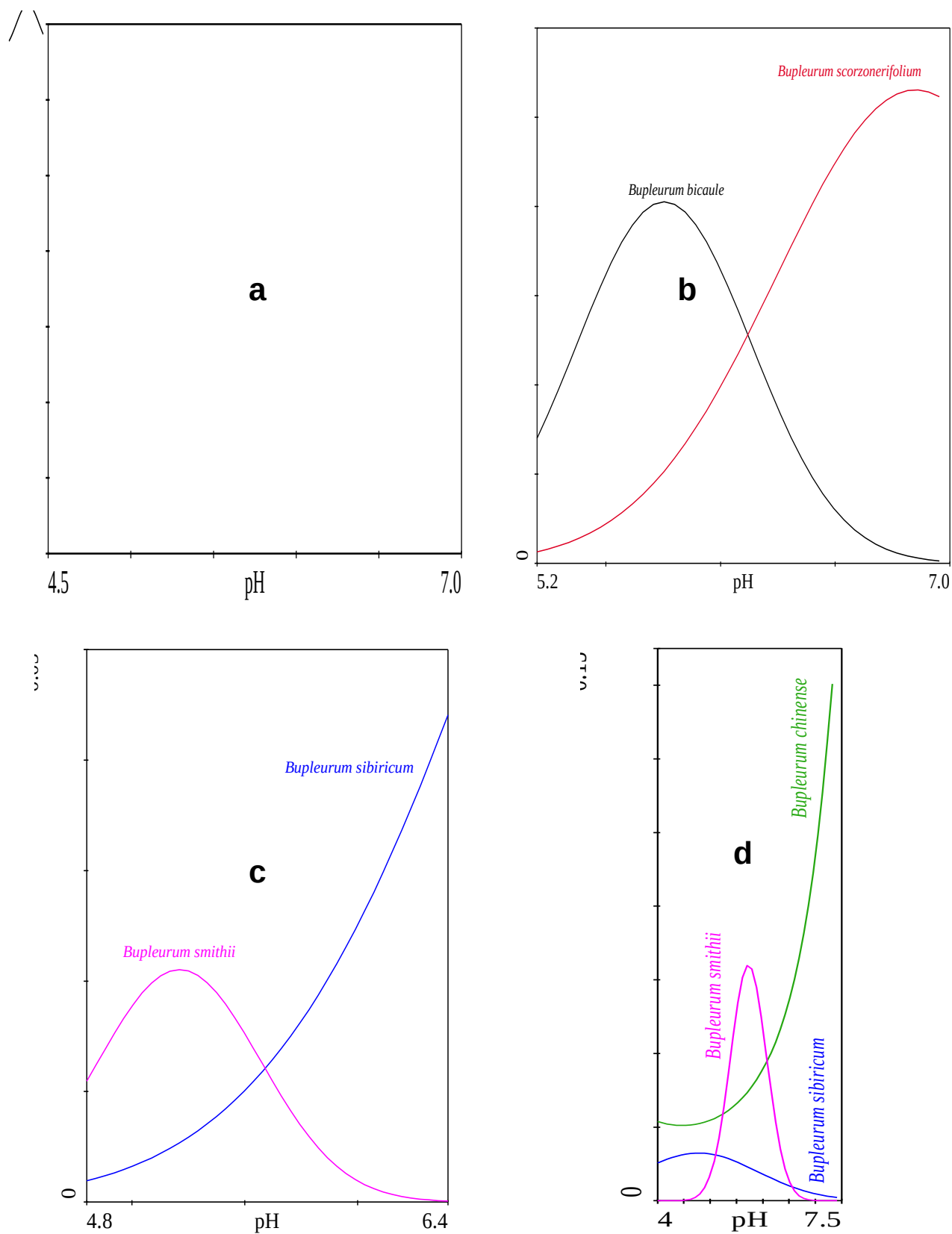


Figure 3. Response curves of *Bupleurum bicaule* (black) and *Bupleurum scorzonerifolium* (red), *Bupleurum sibiricum* (blue), *Bupleurum smithii* (purple) and *Bupleurum chinense* (green) on the variable pH in Guandi (a), Wutai (b), Xiao Wutai (c) and Dongling (d) Mountains.

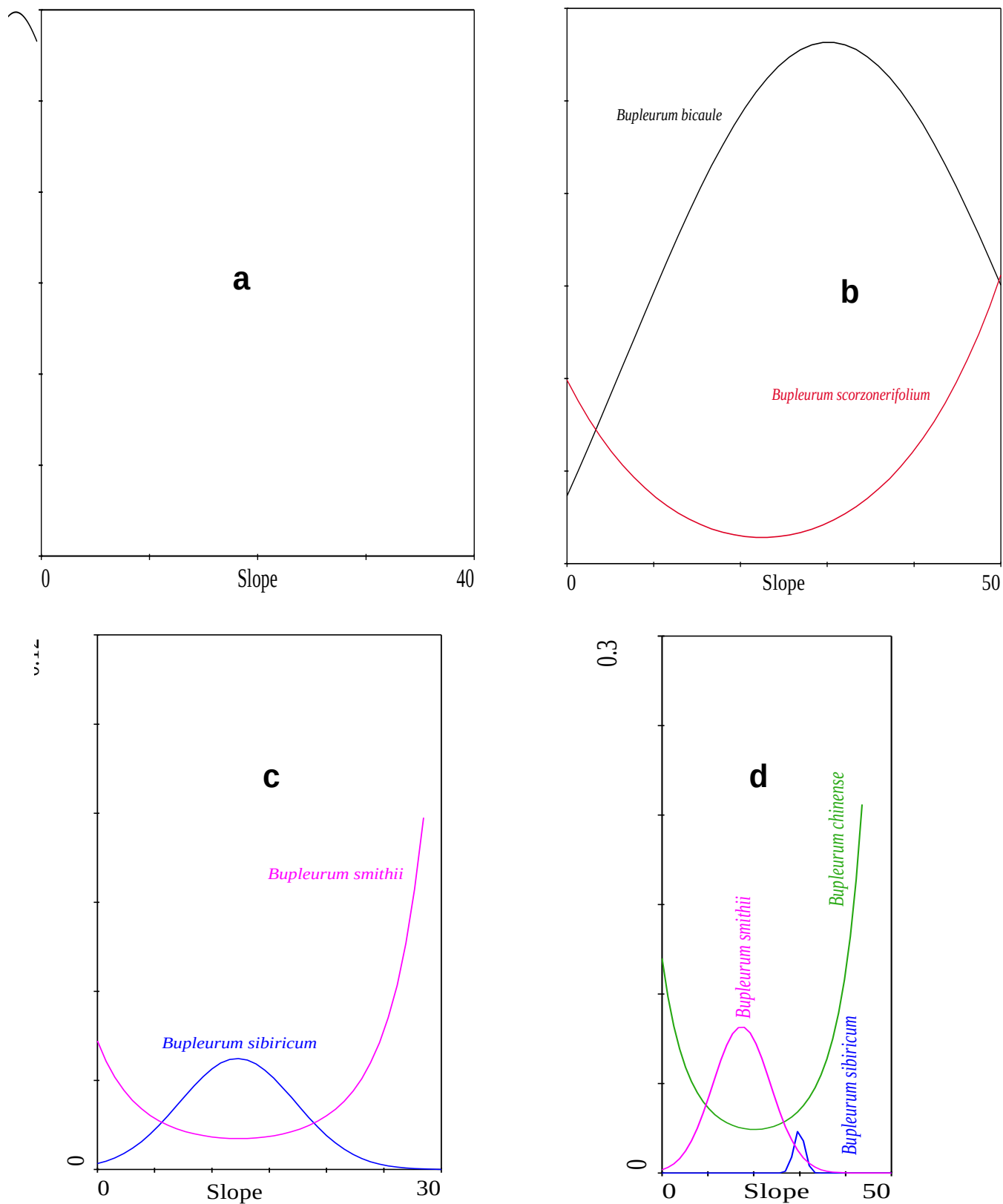


Figure 4. Response curves of *Bupleurum bicaule* (black) and *Bupleurum scorzoniferifolium* (red) *Bupleurum sibiricum* (blue), *Bupleurum smithii* (purple) and *Bupleurum chinense* (green) on the variable slope in Guandi (a), Wutai (b), Xiao Wutai (c) and Dongling (d) Mountains.

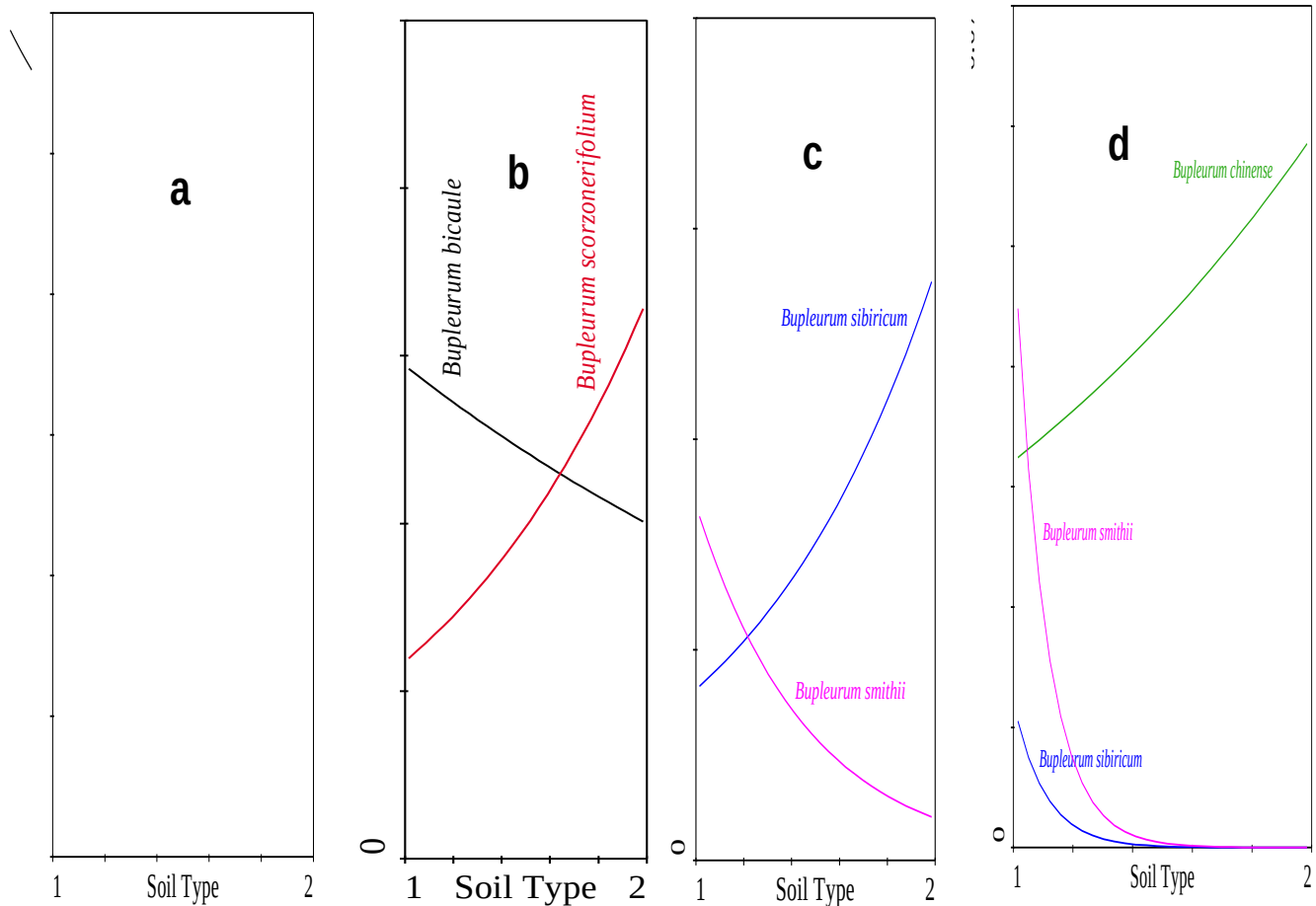


Figure 5. Response curves of *Bupleurum bicaule* (black) and *Bupleurum scorzoniferifolium* (red) *Bupleurum sibiricum* (blue), *Bupleurum smithii* (purple) and *Bupleurum chinense* (green) on the variable soil type in Guandi (a), Wutai (b), Xiao Wutai (c) and Dongling (d) Mountains.

be correlated to vegetation type. Observed differences for *B. sibiricum* and *B. bicaule* could be linked to other specific internal or external factors (Table 6).

DISCUSSION

B. smithii occurred in higher altitude compared to *B. sibiricum* and this latter occurs in higher one than *B. chinense*. In a global way, *B. chinense* occurred between 1400 and 1600 m a.s.l in accordance with Menglan and Watson (2005) who found that this species occurrence was between 1000 and 1700 m a.s.l in the studied geographical area. But our survey showed that *B. chinense* occurred in broadleaves forest and shrubs land contrary to Menglan et al. (2005) who found its occurrence in grass land. We have also found that in Dongling Mountain, *B. chinense* occurred in aspect 40 to 70°, in very slightly acid to neutral environment and in low slope 0 to 10°.

B. smithii occurred between 2100 and 2300 m a.s.l

in accordance with Menglan et al. (2005) who found its occurrence between 1400 and 3700 m a.s.l. This study also found that in Xiao Wutai Mountain, *B. smithii* occurred in aspect beyond 80°, in strongly and medium acid environment, in slope above 25°, in sandy soil, in coniferous forest and grass land. The previous results are not totally in accordance with the one in Dongling Mountain where *B. smithii* occurs in aspect less than 20, in medium acid environment, in slope between 10 and 25°, in loamy soil and in grassland.

B. sibiricum occurred between 1500 and 2100 m a.s.l in accordance with Danren and Li (1974) who found its occurrence between 1500 and 2000 m a.s.l. In Xiao Wutai Mountain, *B. sibiricum* occurred in altitude between 1500 and 1700 m a.s.l, in aspect 30 to 50°, in slightly acid environment, in slope 5 to 25°, in loamy soil and in shrubs land. Except occurrence in loamy soil common to the both sites, in Dongling mountain, *B. sibiricum* occurred in altitude between 1800 and 2100 m a.s.l, in aspect above 80°, in strongly acid environment

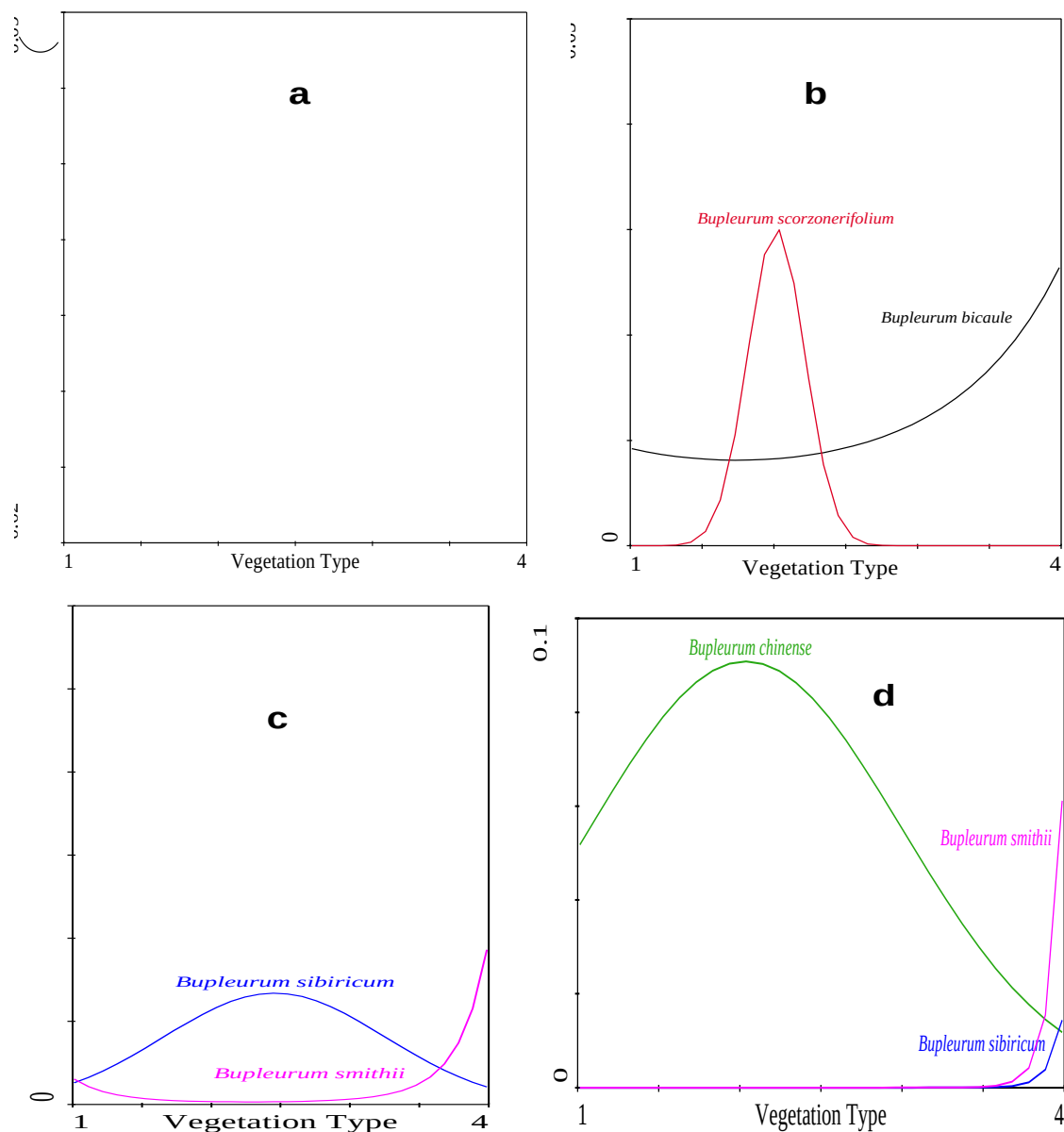


Figure 6. Response curves of *Bupleurum bicaule* (black) and *Bupleurum scorzonerifolium* (red) *Bupleurum sibiricum* (blue), *Bupleurum smithii* (purple) and *Bupleurum chinense* (green) on the variable vegetation type in Guandi (a), Wutai (b), Xiao Wutai (c) and Dongling (d) Mountains.

Table 1. ANOVA summarized results on the variable altitude in the four sites.

Factor	Guandi Mountain	Wutai Mountain		Xiao Wutai Mountain		Dongling Mountain		
	<i>B. bicaule</i>	<i>B. bicaule</i>	<i>B. scorzonerifolium</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. chinense</i>
Altitude	0.45 ^b	0.06 ^b	0.001 ^a	9×10 ^{-5a}	10 ^{-6a}	10 ^{-6a}	2×10 ^{-6a}	5×10 ^{-5a}

Threshold $P \leq 0.05$; ^aSignificant, ^bNon-significant.

Table 2. ANOVA summarized results on the variable slope aspect in the four sites.

Factor	Guandi Mountain	Wutai Mountain		Xiao Wutai Mountain		Dongling Mountain		
	<i>B. bicaule</i>	<i>B. bicaule</i>	<i>B. scorzonerifolium</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. chinense</i>
Slope aspect	0.13 ^b	0.02 ^a	0.11 ^b	0.15 ^b	4.6×10 ^{-6a}	0.30 ^b	0.06 ^b	0.14 ^b

Threshold $P \leq 0.05$; ^aSignificant, ^bNon-significant.

Table 3. ANOVA summarized results on the variable pH in the four sites.

Factor	Guandi Mountain	Wutai Mountain		Xiao Wutai Mountain		Dongling Mountain		
	<i>B. bicaule</i>	<i>B. bicaule</i>	<i>B. scorzonerifolium</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. chinense</i>
pH	0.46 ^b	0.11 ^b	0.20 ^b	0.05 ^a	0.09 ^b	0.19 ^b	0.08 ^b	0.08 ^b

Threshold $P \leq 0.05$; ^aSignificant, ^bNon-significant.

Table 4. ANOVA summarized results on the variable slope in the four sites.

Factor	Guandi Mountain	Wutai Mountain		Xiao Wutai Mountain		Dongling Mountain		
	<i>B. bicaule</i>	<i>B. bicaule</i>	<i>B. scorzonerifolium</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. chinense</i>
Slope	0.04 ^a	0.40 ^b	0.02 ^a	0.07 ^b	0.23 ^b	0.02 ^a	0.03 ^a	0.04 ^a

Threshold $P \leq 0.05$; ^aSignificant, ^bNon-significant.

in slope 25 to 35° and in grass land. Furthermore, vegetation and slope were the only variable to influence in some extent the five recorded *Bupleurum* spp.

Conclusion

The development, structure and function of an organism depend on the interaction of that

organism with its environment. Differences in response could be explained by other environmental variables non-studied in this survey like soil composition, insolation, annual precipitation

Table 5. ANOVA summarized results on the variable soil type in the four sites.

Factor	Guandi Mountain	Wutai Mountain		Xiao Wutai Mountain		Dongling Mountain		
	<i>B. bicaule</i>	<i>B. bicaule</i>	<i>B. scorzonrifolium</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. chinense</i>
Soil Type	0.46 ^b	0.44 ^b	0.30 ^b	0.04 ^a	0.06 ^b	0.05 ^a	0.03 ^a	0.15 ^b

Threshold $P \leq 0.05$; ^aSignificant, ^bNon-significant.

Table 6. ANOVA summarized results on the variable vegetation type in the four sites.

Factor	Guandi Mountain	Wutai Mountain		Xiao Wutai Mountain		Dongling Mountain		
	<i>B. bicaule</i>	<i>B. bicaule</i>	<i>B. scorzonrifolium</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. sibiricum</i>	<i>B. smithii</i>	<i>B. chinense</i>
Vegetation type	0.16 ^b	0.04 ^a	10 ^{-6a}	0.08 ^b	4×10 ^{-5a}	0.02 ^a	10 ^{-5a}	9.5×10 ^{-5a}

Threshold $P \leq 0.05$; ^aSignificant, ^bNon-significant.

precipitation etc. For sustainable management, it would be difficult or impossible to control environmental factors; in this study, vegetation has emerged as a determining factor in the distribution of species. One of the most feasible solutions could be the preservation of these areas from human activity or nevertheless activity controlled by the establishment and strengthening of protected areas. Public awareness is also vitally important.

ACKNOWLEDGEMENTS

This study was supported by the National Natural Foundation of China (No. 30870399). The authors thank Prof. Liu Quanru at the College of Life Sciences of the Beijing Normal University for his precious support in the certification of the collected species and also, Zhao Mingfei from the College of Life Sciences of Beijing Normal University, who participated actively in the field surveys.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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