Fertilization effects on Competitive abilities of *Quercus floribunda* and *Cupressus torulosa* seedlings

Kiran Bargali
Department of Botany, Kumaun University, Nainital-263002 (Uttaranchal)
Email: kiranbargali@yahoo.co.in
surendrakiran@rediffmail.com

Abstract: *Quercus floribunda* Lindl. (tilonj oak) and *Cupressus torulosa* D.Don (surai) form mixed oak-conifer forest in many areas of Central Himalayan region. In the present study, competitive abilities of *Q. floribunda*, and *C. torulosa*, were compared along a gradient of nutrient availability. For this, seedlings of the two species were grown in monoculture (intraspecific competition) and mixed culture (interspecific competition). Adding 0, 144, 264, 384, 504 and 624 mg of 20:20:20 NPK fertilizer per kg soil established a gradient of nutrient availability. In both the species the dry mass yield increased with increasing nutrient availability. At each treatment, the dry mass yield of *C. torulosa* was greater than that of *Q. floribunda* and the difference between the two species was greater in mixed culture. The Relative yield (RY), Relative Crowding coefficient (RCC), Relative competition intensity (RCI) and Absolute competition intensity (ACI) indicated that *C.torulosa* is a better competitor for nutrients than *Q. floribunda*. The relative replacement rates suggest that *C. torulosa* is gaining an advantage over *Q. floribunda* with increasing nutrient availability. [Nature and Science. 2009;7(6):25-29]. (ISSN: 1545-0740).

Keywords: *Quercus floribunda*, *Cupressus torulosa*, dry mass, competition, relative yield, relative competition intensity, relative replacement rate.

Introduction

Competition is an important factor affecting the composition of many plant communities (Tilman 1982, 1988). Relative competitive ability may also depend on the supply of the resource in question and it's relation to other resources (Tilman 1982). There are four possible outcomes of pair- wise interspecific competition (de Wit 1960, Harper 1977): i. Both species perform as they do in interspecific competition; ii. One species grows larger in interspecific competion than it does in intraspecific competition, while the other species grows larger in intraspecific competition; iii. Both species accumulate less biomass in interspecific competition than they do in intraspecific competition (mutual antagonism); iv. Both species grow larger in interspcific competition, than in intraspecific competition.

Quercus floribunda Lindl. (tilonj oak) and *Cupressus torulosa* D.Don (surai) form mixed oak-conifer forest at and around Nainital lying at an elevation of 2000 m (29^o 25' N latitude and 79^o 27' E longitude) in Kumaun Himalaya (Central Himalaya) (Rao 1988). While *Q. floribunda* is a climax species (Troup 1921; Champion and Seth 1968) forming extensive forests in many areas of Central Himalaya, *C. torulosa* has most restricted distribution among the Himalayan species (Champion and Seth 1868). The former is a late successional species and latter is regarded as the colonizer of barren area created by landslides, fire and cutting of forests (Dwivedi and Mathur 1978). In this paper the effect of nutrient availability on competitive abilities of these two contrasting species have been compared. Main objectives of this study were: i. to find out whether competition intensity is more in favourable (high nutrient availability) condition as predicted by Grime (1979); and to test whether early successional *C. torulosa* is a better competitor for nutrient as predicted by Tilman (1982, 1986)(as early successional conditions are relatively nutrient-poor than the late successional conditions).

Materials and Methods

Seedlings of *C.torulosa* and *Q. floribunda* were raised from healthy seeds collected from the seed crop of the same year. Seeds were sown in plastic bags (12 cm x 12 cm x 12 cm) holding 2 Kg of a soil-sand mixture. After germination seedlings were thinned to two seedlings per bag. In one set, each bag contained two individuals of one species only (monoculture). In this set there were 9 bags per species per treatment as described below. In the other set each bag contained one individual of each species (mixed culture) and there were 18 bags per treatment.

The soil material used in this experiment was collected from a *Q. floribunda* stand to a depth of 15 cm. The soil was air dried and sieved through a wire mesh screen (mesh size 1 mm x 1 mm) to remove roots and gravel. The sieved soil contained 0.38% N, 0.11% P and 0.14% K The soil was then mixed with washed commercial sand taken from a nearby river bank (containing negligible nutrient) in 1:3 ratio. This mixture had a pH of 6.6 (measured in a 1:1 soil: water extract). Plastic bags were filled with this soil-sand mixture. A gradient of nutrient availability was produced by adding 0, 144, 264, 384, 504 and 624 mg 20:20:20 NPK fertilizer per kg of soil. Hereafter referred to as N_1, N_2, N_3, N_4, N_5 and N_6 nutrient level, respectively. Plants were watered regularly (at least three times a week). A layer of cotton gauge on the bottom of each bag prevented the soil from being washed away during watering. This experiment was carried out in a glass house at 2000 m a.s.l., where the mean maximum temperature was 1-5^oC higher than the air temperature. Bags were kept for apart from each other to minimize any shading.

Seedlings were harvested (three harvest were taken at 8 months interval), separated into leaves, stem and roots, and oven-dried at 80^oC to constant weight. Leaves shed were collected and weighed.

Statistical analysis of the data was carried out using SPSS(PC+) statistical package for analysis of variance (ANOVA). Means were compared using least significance difference test (LSD). Data were subjected to analysis of variance. Studentized Range Q. procedures (Snedecor and Cochran 1969) were used for discrimination of means where appropriate.

Relative Competition Intensity was calculated as given in Grace (1995):

$$RCI = (P_{mono} - P_{mix}) / P_{mono}$$

where, P_{mono} is dry mass yield (g seedling^{-1}) of a species in monoculture and P_{mix} is dry mass yield in mixed culture. The Absolute Competition Intensity was calculated following Grace (1995):

$$ACI = P_{mono} - P_{mix}$$

Relative Yield Totals (RYT) were calculated RYT = (mean yield of species i in mixed culture/mean yield of species i in monoculture) + (mean yield of species j in mixed culture / mean yield of species j in monoculture). An RYT > 1 indicates growth in mixture exceeds the average growth of each species growing alone i.e. niche differentiation with respect to growth; RYT = 1 indicates the use of identical amount of resource i.e. that competition is not occurring; RYT < 1 implies a mutually antagonistic relationship between the two species. Relative Crowding Coefficients (RCC) were calculated as a measure of competitive ability or aggressivity of one species toward the other: RCC = (mean yield of species i in mixed culture/mean yield of species j in mixed culture) / mean yield of species i in mono culture/mean yield of species j in monoculture). Values of RCC > 1 indicates that species i is competitively superior to species j. The opposite is true when RCC <1.

The relative replacement rates (Vander Bergh 1968; see Bargali 1992) were calculated as follows:

$$\frac{\text{Relative yield of species i at n}^{th}\text{ harvest}}{\text{Relative yield of species j at n}^{th}\text{ harvest}} \ \% \ \frac{\text{Relative yield of species i at m}^{th}\text{ harvest}}{\text{Relative yield of species j at m}^{th}\text{ harvest}}$$

Between harvests, a relative rate > 1 implies that species i is gaining an advantage over species j and values < 1 implies the opposite. In the present study the species i is *Q. leucotrichophora* and the species j is *C. torulosa*. All data are based on dry mass per seedling^{-1}.

Results and Discussion

Dry mass yield

In monoculture as well as mixed culture the drymass yield of both the species increased with increasing nutrient levels (Fig. 1). Analysis of variance indicated that dry mass of seedling was significantly affected by species, competition, nutrient treatment and all their interaction ($P< 0.05$ or 0.01). In monoculture the *Q. floribunda* seedlings has greater dry mass yield than *C.torulosa* particularly towards the lower nutrient gradient, while towards the higher nutrient level the drymass yield was greater for *C. torulosa*. This indicates that being an early successional species *C. torulosa* utilized nutrient according to their availability (Zangerl and Bazzaz 1983). The higher growth rate of *Q. floribunda* seedlings at initial stage was attributed to the higher food reserve in its seeds as compared to *C. torulosa* seeds. However, in mixed culture higher dry mass was reported for *C.torulosa* in all treatments.

When the data of drymass yield were visually analysed for similarity to competitive models given by de Wit (1960) and Harper (1977) then in general model 2 of competitive outcome was observed i.e. one species (*C.torulosa*) grows larger in interspecific competition than it does in intraspecific competition, while the other species (*Q. floribunda*) grows larger in intraspecific competition (Fig. 1). Parrish and Bazzaz (1982) and Bargali (1992) explained that in intraspecific competition, individuals very likely have similarity in genetic identity and consequent limitation in variation in capabilities of using a given resource. However, in interspecific competition individuals are of different species; it is likely that in competition one will be considerably better than the other at obtaining resource. As a result a clear winner or loser may be expected

Relative competition intensity and Absolute competition intensity

The relative competition intensity and Absolute competition intensity data indicate that the growth of *C. torulosa* was increased in presence of *Q. floribunda* while the growth of Q. floribunda was suppressed in the presence of *C. torulosa.* This effect became more pronounced towards the higher nutrient levels (Table 1).

Relative performance of species in mixture

At each nutrient level as well as harvest the relative yield (the yield of a particular species in mixture over its yield in monoculture) of *C. torulosa* was higher than *Q. floribunda* (Table 2). The quotient of relative yield (*Q. floribunda/ C.torulosa*) showed inconsistent pattern along the nutrient gradient. In all treatments Relative yield total was > 1 indicating the niche differences with respect to growth (Table 2). The RCC values were < 1 in all nutrient treatments indicating that *C. torulosa* was a better competitor than *Q. floribunda* in obtaining nutrients. The relative replacement rate indicates that *C.torulosa* is gaining an advantage over *Q. floribunda* particularly towards higher nutrient levels (Table 2). These results indicate opportunistic behaviour of early successional species as they utilize resources according to availability. According to the R-C-S (Ruderal- Competitor- Stress tolerator) model (Grime 1979) competition intensity is presumed to intense with increasing habitat productivity. Zangerl and Bazzaz (1983) also reported competitive superiority of early successional species in resource- rich environments. In addition at low nutrient level, nutrients are present in low amount and species fail to manifest their genetic differences (Parrish and Bazzaz 1982).

To conclude, the result of this study support some previously observed difference between early and late successional species. Maximum production levels were greater in the early successional *C. torulosa* than they were in the later successional *Q. floribunda*. This is consistent with the trend toward decreased net primary production (Odum 1969) and lower net photosynthetic rates (Bazzaz 1979) as succession proceeds. The difference in dry mass of individuals of the two species was lowest at the lowest nutrient level and increased with increasing nutrient level. Competition between species has been noticed to be more intense at higher nutrient levels (Austin and Austin 1980). The early successional *C. torulosa* generally emerged as the more opportunistic of the two as evidenced by greater utilization of resource in proportion to the availability of that resource.

Table 1. Relative competition intensity (RCI) and Absolute competition intensity (ACI) of *Quercus floribunda* and *Cupressus torulosa* as affected by nutrient availability.

Nutrient level	**Harvest**	**RCI**		**ACI**	
		Q. floribunda	*C.torulosa*	*Q. floribunda*	*C.torulosa*
N_1	H_1	0.05	-0.54	0.10	-0.62
	H_2	0.003	-0.15	0.01	-0.43
	H_3	0.01	-0.14	0.06	-0.67
N_2	H_1	0.03	-0.27	0.07	-0.60
	H_2	0.20	-0.25	1.07	-1.13
	H_3	-0.07	-0.08	-0.44	-0.53
N_3	H_1	-0.25	-0.65	-0.77	-1.56
	H_2	0.14	-0.38	1.00	-2.40
	H_3	0.20	-0.33	1.77	-2.94
N_4	H_1	-0.03	-0.31	-0.17	-0.96
	H_2	0.14	-0.35	0.14	-2.90
	H_3	0.09	0.51	1.03	-5.28
N_5	H_1	0.11	-0.32	0.73	-1.39
	H_2	0.19	-0.41	1.97	-3.89
	H_3	0.10	-0.62	1.22	-7.20
N_6	H_1	0.04	-0.45	0.26	-2.91
	H_2	0.16	-0.32	1.87	-3.93
	H_3	0.14	-0.53	2.15	-7.13

Table 2. Relative yield (RY), quotient of relative yield (QRY) relative yield total (RYT), relative crowing coefficient (RCC) and relative replacement rates (RRR) of *Q. floribunda* and *C.torulosa* seedlings in different nutrient levels. H1, H2 and H3 refer to first, second and third harvest, respectively. All data are based on drymass per seedling (g). Nutrient level increases from N1 to N6.

Nutrient level	**Harvest**	**RY**		**QRY**	**RYT**	**RCC**	**RRR**
		Q. flori.	***C.toru.***	**(*Q.flori/C.toru*)**			
N_1	H_1	0.95	1.54	0.61	2.49	0.61	-
	H_2	0.99	1.15	0.86	2.15	0.86	1.41
	H_3	0.99	1.14	0.86	1.13	1.00	1.00
N_2	H_1	0.97	1.27	0.77	2.24	0.77	-
	H_2	0.80	1.25	0.64	2.05	0.64	0.83
	H_3	0.98	1.08	0.91	2.06	0.91	1.42
N_3	H_1	1.25	1.65	0.76	2.90	0.76	-
	H_2	0.86	1.38	0.63	2.24	0.63	0.82
	H_3	0.79	1.33	0.59	1.96	0.59	0.95
N_4	H_1	1.03	1.31	0.79	2.34	0.79	-
	H_2	0.86	1.35	0.64	2.21	0.64	0.81
	H_3	0.90	1.51	0.59	2.22	0.59	0.93
N_5	H_1	0.88	1.32	0.67	2.19	0.67	-
	H_2	0.81	1.41	0.57	2.22	0.57	0.86
	H_3	0.90	1.62	0.56	2.15	0.56	0.97
N_6	H_1	0.96	1.45	0.66	2.41	0.66	-
	H_2	0.83	1.32	0.63	2.15	0.63	0.96
	H_3	0.86	1.53	0.56	2.14	0.56	0.89

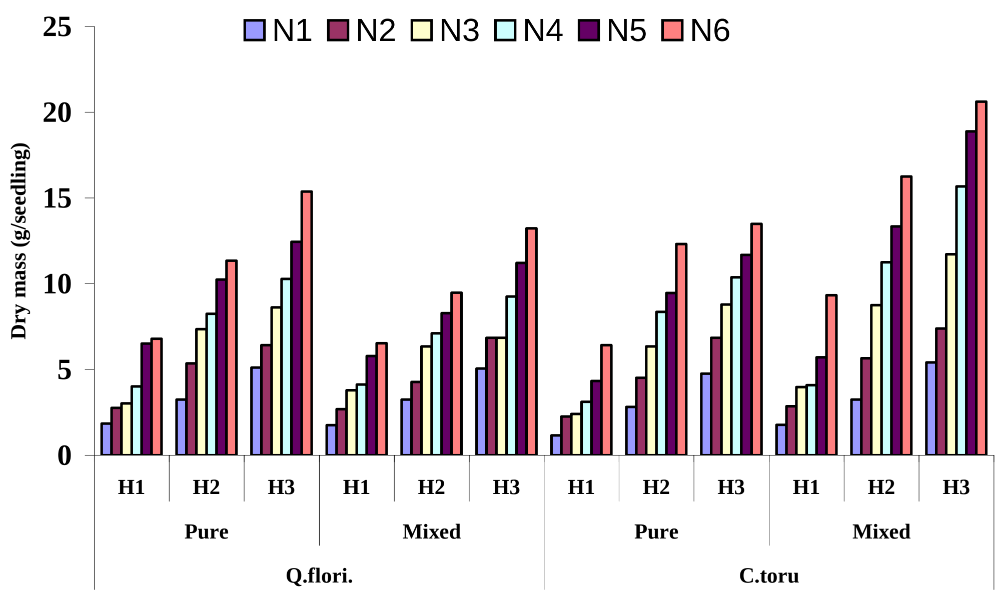

Fig.1. Dry mass of *Quercus floribunda* and *Cupressus torulosa* seedlings as affected by nutrient availabilityH1, H2, H3 denotes harvest 1,2 and 3 respectively; pure indicate monoculture and mixed indicate mixed culture (for detail see materials and methods).

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