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NUTRIENT LOSSES THROUGH COMPLETE HARVESTING FROM SOME MONOCULTURE PLANTATIONS OF PUNJAB

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ABSTRACT ■ In the forest ecosystems nutrients are added to the forest floor by litter fall, decaying roots, animal excreta and canopy wash. These nutrients are finally decomposed and released into soil and ultimately taken up by the plants and retained in the plant biomass. Some released nutrients are stored in the soil and some are lost by leaching, erosion and harvesting of the plants. Thus it is through this dynamic and rather complex system of bio-geo-chemical cycling that the soil organic matter and nutrient supplies are replenished and maintained thereby ensuring continuous productivity of the site.

The present study was conducted in *Eucalyptus* hybrid, *Dalbergia sissoo* and *Acacia catechu* plantations of different ages at different sites in 10 Forest Divisions of Punjab. Biomass of all plant parts of these 3 species have been calculated and nutrient concentration in all plant parts have also been analysed to work out the nutrient accumulation in each plant part (Rawat, 2006).

Trees accumulate nutrients over a period of their growth, which upon harvesting are lost from the site. The extent of loss depends upon the harvesting and utilization intensity. The nutrients accumulated in each plant part are removed after harvesting. Thus, nutrient accumulation in different tree parts of these species are considered to be the net loss of nutrients after harvesting. The net loss of N (nitrogen) in case of *E.* hybrid was found to be up to 675.93 kg ha^{-1} (about 33.6%); in *D. sissoo* it was up to 2087 kg ha^{-1} (42 %) and in *A. catechu* it was up to 1041 kg ha^{-1} (35.6 %). Similarly loss of P (phosphorus) was up to 52.65 (2.6%) in *E.* hybrid, 98.05 (1.99%) in *D. sissoo* and 92.75 (2.76%) in *A. catechu*. Loss of K (potassium) was up to 547.47 (27.2%) in *E. hybrid*, 1305.4 (20.8%) in *D. sissoo* and 767.05 (22.8%) in *A. catechu*. Calcium loss was up to 1010.22 (59.7%) in *E. hybrid*, 3306.38 (52.8%) in *D. sissoo* and 1385.41 (41.1%) in *A. catechu* and loss of magnesium up to 62.98 (5.7%) in *E. hybrid*, 141.20 (2.8%) in *D. sissoo* and 80.13 (2.4%) in *A. catechu*.

The results clearly show substantial losses of nutrients after harvesting from these plantations. Thus harvesting may seriously deplete the pool of nutrients in a stand without any doubt.

Key words: Nutrient accumulation / loss, complete harvesting, *Eucalyptus* hybrid, *Dalbergia sissoo*, *Acacia catechu*, Punjab.

INTRODUCTION

Nutrients are constantly being added or removed from the ecosystems by artificial or natural processes. In the forest ecosystems nutrients are imported by wind, rain dust and animal life and are returned to the forest floor

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by litterfall, decaying roots, animal excreta and canopy wash. These nutrients are finally decomposed and released into soil and ultimately taken up by the plants and retained in the plant biomass. Some released nutrients are stored in the soil and some are lost by leaching, erosion and harvesting of the plants. Thus it is through this dynamic and rather complex system of bio-geo-chemical cycling that the soil organic matter and nutrient supplies are replenished and maintained thereby ensuring continuous productivity of the site.

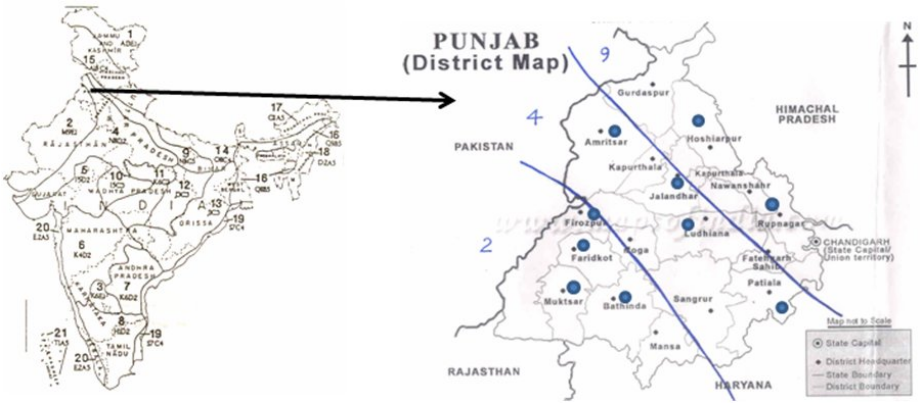
Trees accumulate nutrients over a period of their growth, which upon harvesting are lost from the site. The extent of loss depends upon the harvesting and utilization intensity. Earlier only heartwood portion was removed (which generally contains a low concentration of nutrients) leaving behind much of the biomass on site. This was characterised as "wasteful" harvesting. This caused only a small portion of nutrients lost. Later this had been replaced by a "less wasteful' type harvesting by utilizing each and every component of tree. This followed removal of increased amount of nutrients (Kimmins, 1987). It was only during 1980s attention was given by forest scientists / managers on the extent of nutrient withdrawals in harvesting, while switching over from conventional to 'whole tree harvesting' (WTH) (removal of all above ground tree components) and to 'complete tree harvesting' (CTH) (removal of even tree stumps and root system) (Young, 1964).

Tree species, rotation age and site productivity can modify the impact of increased biomass removal on site nutrient. Hardwood species have more nutrient concentration than coniferous species (Voigt, 1968), hence removal of equal biomass will result in greater nutrient drain from hardwood than from conifer stand.

The present studies were conducted in *Eucalyptus* hybrid, *Dalbergia sissoo* and *Acacia catechu* plantations at different Forest Divisions of Punjab Forest Department.

STUDY SITES

The present study was conducted in *Eucalyptus* hybrid (18-30years age), *Dalbergia sissoo* (25-33 years age) and *Acacia catechu* (20-32 years age) plantations of different ages at different sites in 10 Forest Divisions of Punjab namely Amritsar, Ludhiana, Hoshiarpur, Patiala, Muktsar, Jalandhar, Bhatinda, Ferozepur, Faridkot, Roopnagar/Ropar representing three agro-climatic zones of Punjab (Sehgal *et al*.1990) as clearly shown in the Map.



Map. Location of study sites in Punjab.

MATERIALS AND METHODS

Biomass estimation

Stratified tree technique method of Art and Marks (1971) was used to harvest the sample trees. Temporary sample plots were laid out in all the plantations of the species and the diameter at breast height (DBH) of all the standing trees in the sample plots, heights of 15 representative sample trees of all the diameter classes were recorded. The entire diameter range was then divided into different diameter classes. Three sample trees from each diameter class (close to the mean DBH of that class) were harvested for biomass estimation. All the tree components (leaves, twigs, branches, bark, bole) including roots were separated immediately after felling and their fresh weights recorded in the field. The representative samples of each tree component (100 g each of leaves, twigs, branches, bark, fruit & root) were taken for oven dry weight estimation and chemical analysis for different macronutrients in the Laboratory.

The bole portion of the sample trees was cut into 2m long sections (billets) for convenience of weighing. Approximately 5-cm broad disc was removed from the base of each billet for estimation of fresh and dry weights and nutrient analysis.

Nutrient analysis of plant components

The representative samples of all the tree components and litter samples were digested with wet digestion method of Piper (1950) for analysis of Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg). P was estimated by 'Molybdate blue' method (Vogel, 1961) and K and Ca were estimated by 'EEL' Flame Photometer as per Vogel, (1961), whereas Mg was estimated by 'Thizole yellow' method of Young & Gill (1951) by using colorimeter. Nitrogen (N) was estimated by 'Macro Kjeldahl' method.

Nutrient accumulation / loss (kg ha^{-1})

The percent (%) nutrient concentration, weight (kg tree^{-1}) of all the tree components and number of total trees present per hectare were used for calculating nutrient retention / accumulation kg ha^{-1}.

RESULTS AND DISCUSSION

Figure 1 depicts the average percentage concentration of different nutrients in different plant components. The highest percentage is of N (1.33%), P (0.08%), Mg (0.05%) in the leaf, while fruit has maximum percentage of K (1.05%) and bark has highest of Ca (1.25%). The highest value of N in leaf is followed by bud/fruit (0.09/0.84%), then by root (0.41%), then by twig (0.34%), branch and bark (0.32%) and lowest in bole (0.15%).

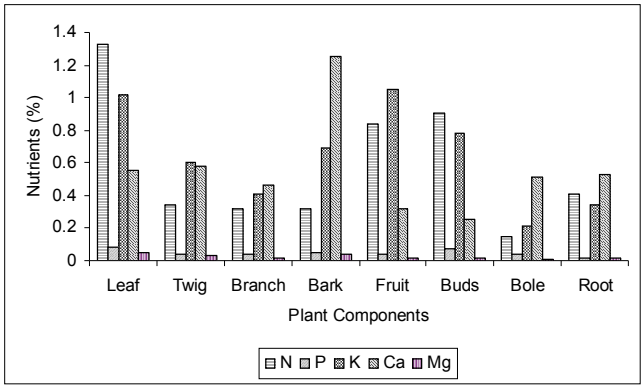


Figure 1. Nutrients concentration (%) of *E.* hybrid in different tree components

P concentration in leaf followed by buds, bark, twig/branch, bole and root. In case of K the descending order is fruit, leaf, bud, bark, twig, branch, root and bole, respectively. Ca concentration is highest in bark than in twig, leaf, root, bole, branch, fruit and buds, respectively. The highest concentration of Mg in leaf was followed by bark, twig, branch-fruit-buds-roots and bole.

The high percentage of Ca in the bark of *Eucalyptus* (smooth barked species) has been reported by George (1977) and Negi (1984) also.

Figure 2 depicts the average percentage concentration of different nutrients in different plant components. The highest percentage is of N (2.65%) and Mg (0.11%) in the leaf, while fruit has maximum percentage of K (1.29%) and P (0.11%) and bark has highest of Ca (2.30%). The highest value of N in leaf is followed by fruit (2.44%), then by twig (1.41%), then by bark (1.14%) then root (1.05%), then branch (0.76%) and lowest in bole (0.58%).

Similarly P concentration in fruit followed by leaf, twig, root, branch- bark and bole. In case of K the descending order is fruit, leaf, root, bark, twig, bole and branch, respectively. Ca concentration is highest in bark then in twig, leaf, fruit, root, twig, branch and bole, respectively. The highest concentration of Mg in leaf was followed by bark, branch, bark, twig-fruit, roots and bole.

Figure 3 depicts the average percentage concentration of different nutrients in different plant components. The highest percentage is of N (2.50%) P (0.36%) and K (1.06%) in the fruit, where as Mg (0.07%) was highest in leaf and bark, the maximum percentage of Ca (1.45%) is highest in bark. The highest value of N in fruit is followed by leaf (2.36%), then by bark (1.39%), then by twig (0.93%), then root (0.82%), then branch (0.63%) and lowest in bole (0.26%).

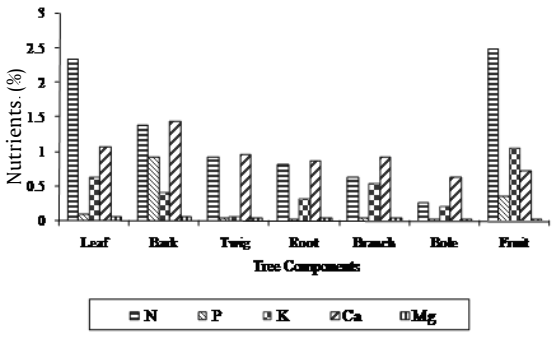


Figure 3. Concentration (%) of nutrients in different plant components of *A. catechu*.

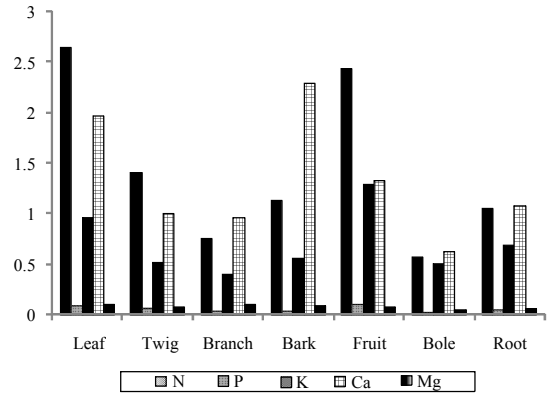


Figure 2. Concentration (%) of nutrients in different plant components of *D. sissoo.*

P concentration in fruit followed by leaf, twig-branch, root, and bark-bole. In case of K the descending order is fruit, leaf, branch, bark, root, bole and twig, respectively. Ca concentration is highest in bark then in leaf, twig, branch, root, fruit and bole, respectively. The highest concentration of Mg in leaf and bark was followed by twig, branch-roots, fruit, and bole, respectively.

Nutrient accumulation or losses (kg ha^{-1})

The total nutrient (kg ha^{-1}) accumulated in a tree or and in various tree components in all the trees present in the plantations or study

sites are depicted in tables 1,2 and 3 in case of *E*. hybrid, *D. sissoo* and *A. catechu*, respectively. These are on the basis of the average nutrient concentrations of each component and their corresponding biomass (kg ha^{-1}) as per Rawat (2006) of these three species.

It is observed that the amount of nutrient accumulated is directly related to the biomass produced by different components of different stands and the concentration of different nutrient elements in the various tree components. As such, the nutrient accumulation in different tree components varies considerably. Though leaves contain the highest percentage of N, P and K, the actual nutrient concentration (kg ha^{-1}) is not higher in the leaves, but it is higher in the bowl as is evident from the tables. For example N concentration in leaves is 1.33% and its total leaf nutrient content varies from 11.73 to 44.39 kg ha^{-1}, while on the other hand N-concentration in the bowl is 0.15% and the total bole nutrient content varies from 34.91 to 309.74 kg ha^{-1} in case of *E*. hybrid. This is due to the fact that bole dry weight is far greater than the leaf weight. The same holds true for other nutrients also. However, Ca is higher in bark than other components; this is because of higher concentration of Ca in Bark.

On unit area basis the amount of various nutrients accumulated in the total biomass of *Eucalyptus* hybrid varies from (N) 81.10 kg ha^{-1} to 675.93 kg ha^{-1}, (P) 11.87 kg ha^{-1} to 52.65 kg ha^{-1}, K- 83.94 kg ha^{-1} to 547.47 kg ha^{-1}, Ca- 109.63 kg ha^{-1} to 1010.22 kg ha^{-1} and Mg – 6.92 kg ha^{-1} to 62.98 kg ha^{-1}. These variations are attributed to the variability in the total biomass (kg ha^{-1}) produced by the stands. Considering the percentage contribution of different nutrients to total nutrients (kg ha^{-1}) it is found that the maximum contribution of Ca (33.55 % to 59.68%) is followed by N (12.18 to 33.62%), then K (17.34 to 28.96%), P is 1.77 to 4.04% and Mg 1.36 to 5.70%, respectively, in case of *E.* hybrid.

In case of *D. sissoo* the amount of different nutrients accumulated in total biomass varied from N- 691.12 kg ha^{-1} to 2087.24 kg ha^{-1}, P 26.33 to 98.05 kg ha^{-1}, K 470.2 to 1305.4 kg ha^{-1}, Ca 725.05 to 3306.38 kg ha^{-1} and Mg 58.33 to 141.20 kg ha^{-1}. The percentage contribution of different nutrients to total nutrients is N (24.57 to 42.41%), P (1.28 to 2.1%), K (16.69 to 31.95%), Ca (28.25 to 54.79%) and Mg (1.51 to 4.27%), respectively.

In case of *A. catechu* the amount of various nutrients varies from N- 482.19 to 1041.04 kg ha^{-1}, P- 30.32 to 92.75 kg ha^{-1}, K- 194.81 to 767.05 kg ha^{-1}, Ca 523.3 to 1425.59 kg ha^{-1} and Mg- 27.27 to 80.13 kg ha^{-1} respectively. The percentage contribution of different nutrients to total nutrients are as; N (29.78 to 35.61%), P (1.61 to 2.76%), K (11.35 to 22.79%), Ca (38.64 to 54.86%) and Mg (2.01 to 2.61%), respectively.

Pande *et al.* (1987) have reported that in a 7 years stand of *A. auriculiformis* (Bihar) maximum accumulation of NPK was in leaf and twigs probably due to higher concentration of these in leaf and comparatively less in bole: N 120, P 2, K 39, Ca 61, Mg 20 kg ha^{-1} and 47.8% N, 76.2% P, 54.4 % K, 43.7% Ca, 37.5% Mg.

Table 1: Nutrient accumulation (kg ha^{-1}) in different tree components of *E.* hybrid

Site: -TEC Patiala								
	Tree components						Total	
Nutrients	Leaf	Twig	Branch	Bark	Bole	Root	kg ha^{-1}	%
N	44.39	13.99	62.69	59.84	309.74	185.29	675.93	33.62
P	2.32	1.28	6.75	5.57	32.51	4.21	52.65	2.62
K	41.29	22.39	61.72	95.12	198.51	128.44	547.47	27.23
Ca	26.50	27.99	81.98	186.10	149.92	202.13	674.61	33.55
Mg	4.31	2.45	4.34	7.00	29.39	12.63	60.12	2.99
						Total	2010.77	100.00
Site: -Kamalpur (Amritsar)								
N	25.68	14.21	39.94	30.14	113.03	48.47	271.47	16.04
P	1.63	1.25	4.58	4.45	13.93	4.04	29.89	1.77
K	14.09	12.09	50.34	75.74	157.93	43.85	354.03	20.92
Ca	6.26	14.17	73.91	127.58	695.97	92.32	1010.22	59.68
Mg	0.41	0.38	3.47	5.86	15.48	1.44	27.04	1.60
						Total	1692.65	100.00
Site: -Doraha (Ludhiana)								
N	14.12	5.00	18.32	14.14	101.09	53.29	205.97	18.63
P	0.98	0.47	2.04	3.49	14.73	2.80	24.50	2.22
K	12.93	4.54	19.38	2.92	120.50	31.41	191.69	17.34
Ca	5.28	3.78	19.38	19.23	522.18	50.49	620.34	56.12
Mg	0.45	0.47	1.84	47.09	10.04	3.09	62.98	5.70
						Total	1105.48	100.00
Site: -Dholbaha (Hoshiarpur)								
N	23.88	4.77	12.75	11.45	59.12	29.35	141.32	16.84
P	1.64	0.60	2.33	2.62	9.10	2.83	19.12	2.28
K	12.88	13.94	26.21	29.43	103.95	39.60	226.01	26.94
Ca	9.37	7.68	17.95	71.49	298.38	35.36	440.22	52.47
Mg	0.53	0.44	1.80	1.13	6.98	1.41	12.29	1.46
						Total	838.96	100.00
Site: -Katour								
N	19.07	2.84	14.21	16.53	69.59	31.35	153.59	12.18
P	1.29	0.84	3.05	2.11	19.32	1.08	27.68	2.20
K	16.49	5.22	18.27	40.29	252.49	32.43	365.19	28.96
Ca	9.21	4.68	20.30	47.11	572.89	43.24	697.43	55.31
Mg	0.23	0.23	1.02	1.76	10.32	3.54	17.10	1.36
						Total	1260.98	100.00
Site: -Kharkan								
N	11.73	2.90	6.03	7.49	34.91	18.04	81.10	27.63
P	0.70	0.39	1.17	2.34	6.08	1.19	11.87	4.04
K	9.54	4.45	8.81	15.82	29.18	16.14	83.94	28.60
Ca	3.85	4.11	11.67	29.67	27.09	33.24	109.63	37.36
Mg	0.17	0.11	0.32	1.33	4.52	0.47	6.92	2.36
						Total	293.46	100.00

Table 2: Nutrients accumulation (kg ha^{-1}) in different tree components of *D. sissoo*

Site: - Nara (Hoshiarpur)								
Nutrients	Tree components						Total kg ha^{-1}	%
	Leaf	Twig	Branch	Bark	Bole	Root		
N	175.32	102.71	330.53	196.90	162.73	307.59	1275.78	24.57
P	10.63	6.99	34.71	9.04	8.56	13.44	83.37	1.61
K	99.53	65.68	191.71	101.90	139.18	268.77	866.76	16.69
Ca	294.08	188.64	718.91	445.08	481.77	716.71	2845.19	54.79
Mg	8.14	8.03	28.10	18.15	38.54	20.90	121.87	2.35
						Total	5192.98	100.00
Site: - Chaksadhu								
N	109.36	175.84	230.05	159.27	1171.96	240.75	2087.24	42.41
P	4.37	8.68	13.84	5.77	49.81	15.57	98.05	1.99
K	49.37	36.54	117.62	75.70	550.59	181.70	1011.51	20.55
Ca	72.65	86.78	449.73	269.30	445.71	259.57	1583.74	32.18
Mg	6.87	7.54	18.16	13.75	78.66	16.22	141.20	2.87
						Total	4921.75	100.00
Site: -Dhirowal								
N	52.90	77.11	77.55	127.04	113.88	242.64	691.12	33.51
P	2.52	4.88	3.06	5.17	5.06	5.64	26.33	1.28
K	21.55	30.84	29.41	48.12	206.26	134.01	470.20	22.80
Ca	44.78	54.66	35.53	201.18	253.08	197.49	786.72	38.15
Mg	3.45	4.69	35.53	13.64	15.18	15.52	88.00	4.27
						Total	2062.38	100.00
Site: -Kharkan								
N	77.73	53.53	181.66	157.42	182.57	225.84	878.76	34.24
P	2.77	3.06	9.08	4.76	25.18	8.52	53.37	2.08
K	29.64	11.52	83.26	46.49	554.01	95.17	820.10	31.95
Ca	92.22	25.96	143.82	262.90	100.73	99.43	725.05	28.25
Mg	6.72	4.23	20.44	17.70	18.89	21.31	89.27	3.48
						Total	2566.56	100.00
Site: -Dharamkot (Ferozpur)								
N	71.53	83.21	116.22	125.71	147.83	200.26	744.76	31.85
P	2.30	2.15	5.33	5.02	9.27	18.93	43.00	1.84
K	26.43	33.60	61.02	48.29	153.62	160.20	483.15	20.66
Ca	39.74	62.51	154.96	235.15	318.59	198.07	1009.02	43.15
Mg	2.49	6.45	9.20	7.06	17.84	15.29	58.33	2.49
						Total	2338.27	100.00
Site: - Kamalpur (Amritsar)								
N	38.91	43.94	232.37	348.18	449.54	366.34	1479.28	23.60
P	1.83	2.49	14.21	11.68	38.46	12.44	81.10	1.29
K	14.76	28.42	166.41	328.62	554.30	212.89	1305.40	20.83
Ca	11.81	17.58	182.65	1068.32	1820.05	205.98	3306.38	52.76
Mg	0.65	1.46	5.07	19.63	58.35	9.68	94.85	1.51
						Total	6267.01	100.00

Table 3: Nutrient accumulation (kg ha^{-1}) in different tree components of *A. catechu*

Site: -Dholbaha-Baruti (Hoshiarpur)								
Nutrients	Tree components						Total kg ha^{-1}	%
	Leaf	Twig	Branch	Bark	Bole	Root		
N	35.11	22.96	129.44	127.88	108.55	136.70	560.64	29.78
P	1.89	2.99	6.08	3.16	7.12	9.08	30.32	1.61
K	7.94	14.88	53.10	34.40	48.49	55.53	214.35	11.38
Ca	22.28	43.66	320.84	175.32	235.79	234.95	1032.83	54.86
Mg	1.74	1.70	12.72	7.60	10.68	10.15	44.59	2.37
						Total	1882.73	100.00
Site: -Jahankhelan								
N	50.96	27.71	62.05	96.23	112.03	133.21	482.19	35.61
P	1.86	2.89	5.52	3.18	12.14	5.07	30.65	2.26
K	16.64	14.46	75.15	26.58	105.49	52.55	290.87	21.48
Ca	24.51	27.71	48.26	83.46	228.72	110.62	523.30	38.64
Mg	1.63	1.93	2.76	4.67	11.67	4.61	27.27	2.01
						Total	1354.28	100.00
Site: -Baruti Chauhal.								
N	117.30	66.77	100.71	202.85	231.81	229.08	948.53	33.39
P	5.23	5.07	15.14	3.24	18.58	8.55	55.82	1.96
K	30.06	59.26	117.17	69.56	242.57	99.15	617.78	21.75
Ca	29.41	24.35	105.32	196.36	669.03	136.77	1161.24	40.88
Mg	1.96	2.03	5.92	9.98	25.43	11.97	57.30	2.02
						Total	2840.66	100.00
Site: -Seonk I (Roopnagar / Ropar)								
N	93.98	41.98	132.25	149.08	217.52	268.52	903.34	32.23
P	5.51	6.19	7.65	4.52	18.33	19.07	61.26	2.19
K	22.77	29.76	56.83	28.68	99.60	101.69	339.33	12.11
Ca	60.07	88.39	344.28	199.32	360.14	373.39	1425.59	50.87
Mg	5.38	3.24	18.58	10.14	19.92	15.89	73.15	2.61
						Total	2802.66	100.00
Site: -Seonk II								
N	78.69	43.42	66.03	90.10	120.84	134.26	533.34	31.29
P	4.11	6.20	3.87	2.32	9.81	9.52	35.83	2.10
K	17.30	28.85	29.74	17.56	47.27	54.10	194.81	11.43
Ca	44.30	83.74	161.21	124.59	263.08	220.42	897.35	52.65
Mg	3.06	3.10	7.44	5.93	12.93	10.52	42.98	2.52
						Total	1704.31	100.00
Site: -Siswan Pallanpur								
N	68.57	104.92	170.81	174.67	305.70	216.37	1041.04	30.92
P	3.30	10.10	33.33	3.61	27.49	14.92	92.75	2.76
K	17.63	87.52	208.31	64.96	299.11	89.53	767.05	22.79
Ca	22.03	44.88	229.14	185.78	754.36	149.22	1385.41	41.15
Mg	1.65	3.93	14.58	10.25	36.29	13.43	80.13	2.38
						Total	3366.38	100.00

The nutrients accumulated in each plant part are removed after harvesting. Thus, the net losses of nutrients from *E*. hybrid, *D. sissoo* and *A. catechu* plantations are depicted in Tables 1, 2 and 3, respectively, in kg ha^{-1} basis and described as nutrient accumulation in different parts. Hence, the net loss of nitrogen could be up to 675.93 kg ha^{-1} or up to about 33.6% in *E.* hybrid; 2087 kg ha^{-1}, 42 % in *D. sissoo* and 1041 kg ha^{-1} (up to 35.6 %) in *A. catechu.* Similarly loss of phosphorus could be up to 52.65 (2.6%) in *E.* hybrid, 98.05 (1.99%) in *D. sissoo* and 92.75 (2.76%) in *A. catechu*. Loss of potassium may be up to 547.47 (27.2%) in *E. hybrid*, 1305.4 (20.8%) in *D. sissoo* and 767.05 (22.8%) in *A. catechu*. Calcium loss could be up to 1010.22 (59.7%) in *E. hybrid*, 3306.38 (52.8%) in *D. sissoo* and 1385.41 (41.1%) in *A. catechu* and loss of magnesium could be up to 62.98 (5.7%) in *E. hybrid*, 141.20 (2.8%) in *D. sissoo* and 80.13 (2.4%) in *A. catechu*.

The results clearly show substantial losses of nutrients after harvesting from these plantations. Thus harvesting may seriously deplete the pool of nutrients in a stand without any doubt.

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